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INTERNATIONAL RAILWAY CONGRESS
ASSOCIATION
(ENGLISH EDITION)

[625. 617 (.44)]

A solution of the transhipment question,

By P. BACLE,
Chief Engineer and Chief Service Official of the Somain-Anzin-Belgian Frontier Railway.

Figs. 1 to 4, pp. 381 to 383.

Unknown, or at any rate neglected, before the war, by reason of the relative abundance and cheapness of labour, the question of the cost of transhipment at the point of junction of a narrow gauge line with a standard gauge line has become so important at the present day that the fate of the traffic of many small railway systems depends directly upon it. In many cases the situation is further aggravated by the competition of motor lorries, that form of transport enabling the trader to effect substantial economies by delivering his goods direct to the main line station, thereby avoiding the cost of transhipment. It is therefore essential, if the future of certain railways is to be assured, that they should make such arrangements as will reduce to a minimum the cost of the various operations entailed in the handling of goods.

The Anzin Mines Company has had to solve a problem of this nature in the course of the last few years in order to be in a position to maintain and extend its outlets in the region served by the Cambrésis Railway. This Company, whose numerous undertakings are linked up with the public standard gauge railway running from Somain to the Belgian frontier, possessed, prior to the war, at Denain, near to the Renard pit, an exchange station for transhipment between standard gauge and narrow gauge wagons. The installation then consisted simply of a steam crane for the manipulation of small and unscreened coal, screened coal being transhipped in baskets. All operations were carried out by hand and the staff, consisting of four men and two women, handled an average of about 100 tons per day. When after the war, during which the transhipment station had been destroyed, it was necessary to re-establish contact with the Cambrésis Railway, the scarcity of labour prohibited a return to the former installations which, apart from low output, had the further disadvantage of damaging the coal owing to the number of handlings involved. In the circumstances an endeavour was made to discover a solution by which the narrow gauge wagons could be brought right up to the loading points, thereby avoiding any transhipment of the goods despatched. Solutions which had already been tried elsewhere (e. g. a third rail, narrow gauge inside the standard gauge, etc.) were immediately excluded as unsuitable, in view of the complexity of the railway system in question. The solution finally resorted to was the transporting of the narrow gauge wagon on a flat wagon which could, without any special precautions, be marshalled in the heavy trains of the Anzin Railway, and which could be shunted, even while carrying the narrow gauge wagon, like any ordinary vehicle.

The design of the wagon to be used for this purpose was studied jointly by the technical staff of the Anzin Company and by the Rhonelle Workshops at Marly, where the wagons were to be built. They have now been in use for more than a year and, in their final form, have performed perfectly the service for which they were designed.

General description of the wagon.

The wagon has a total length over the buffers of 7.44 m. (24 ft. 5 in.), and a width of 2.15 m. (7 ft. 5/8 in.). The headstocks have a total width of 2.43 m. (7 ft. 11 11/16 in.). The wheel base is 3 m. (9 ft. 10 1/8 in.). The wheels have a diameter on the tread of 0.65 m. (2 ft. 1 5/8 in.), and the axle journals are 0.205 m. × 0.105 m. (8 5/64 × 4 1/8 in.). The wagon consists essentially of two sole bars connected by double cross bars made of steel which carry the rails on which the narrow gauge wagon stands (fig. 1). The two headstocks are not fixed to the sole bars; they can be lowered horizontally, round a pivot pin situated on the lower part of the underframe, so as to form the bridge necessary for loading and offloading the wagon.

The headstock is securely fastened and cottered up to the underframe when in the running position (fig. 3). The narrow gauge wagon is secured on the flat wagon by means of four screwed shackles. One end of each of these shackles is fixed by means of a link to an eye bolt rivetted on to the sole bar of the wagon; the other end engages in a hook bolted near the end of the headstock of the narrow gauge wagon. Four links on the free ends of the shackles make it possible to rope wagons of varying lengths (fig. 2). In this way the wagon carried can be tightly and safety secured to the flat wagon carrying it.

Equipment of transhipment station.

The loading and offloading of narrow gauge wagons on to the special wagons is done at the junction of the two railway systems. The narrow gauge line is laid as a continuation of the standard gauge line, but at a higher level; the difference in level is 0.59 m. (1 ft. 11 1/4 in.), and corresponds to the difference in height between the top of the rails on the wagon and that of the rail on the standard gauge line (fig. 3). As dropping the truck headstock, and lifting it up again to in its normal position, required a considerable effort, these operations are effected by means of pulley blocks, carried on a steel gantry and worked by an electric motor (fig. 4). Electric capstans are used for bringing up the wagons to the exchange point. The whole sequence of operations, comprising releasing and lowering the wagon headstock, the offloading of a loaded wagon, the loading of an empty wagon and the replacing of the headstock in its normal position, takes on an average about ten minutes.

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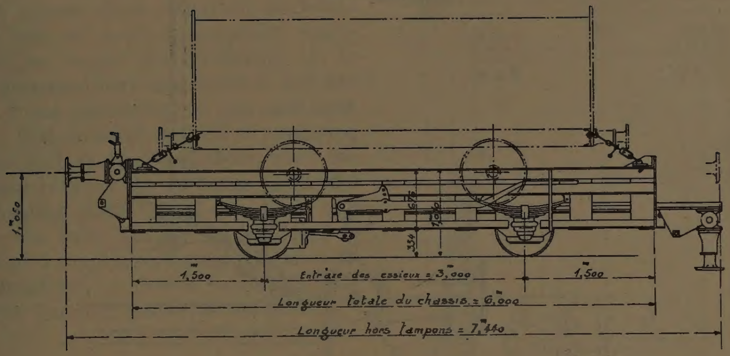
The tests carried out when these wagons were first put into service showed that they could be treated in the same way as

Elevation.


1,050
675
1,000
334
1,500
Entr'axe des essieux = 3,000
1,500
Longueur totale du chassis = 6,000
Longueur hors tampons = 7,440

Plan.

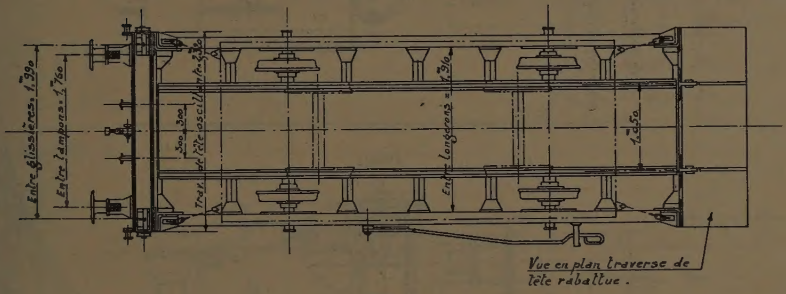
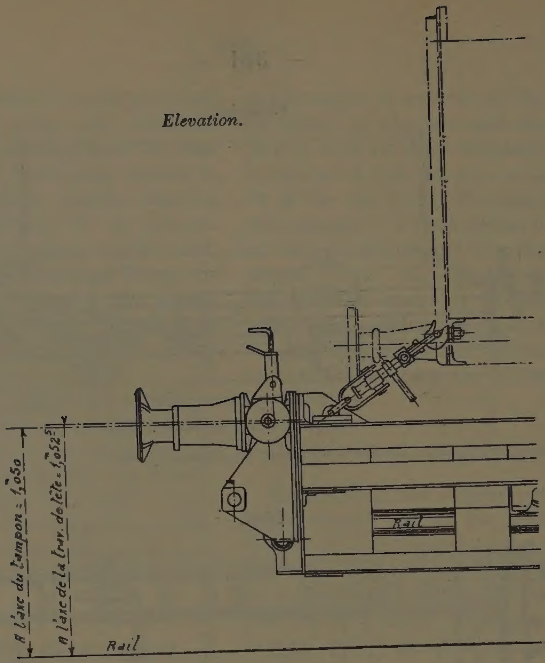


Fig. 1.

Explanation of French terms : **Entr'axe des essieux = Between wheel centres. — Longueur totale du chassis = Total length of frame. — Longueur hors tampons = Length over buffers. — Entre glissières = Between guides. · Entre tampons = Between centres of buffers. — Vue en plan, traverse de tête rabattue = Plan view, headstock lowered.**

any ordinary wagons. The method of securing the headstocks, which was one of the weak points, has proved perfectly satisfactory, and the wagons are regularly marshalled in trains weighing as much as 1 500 tons gross, running at from 40 to 45 km. (25 to 28 miles) an hour. The system employed for fastening the narrow gauge wagons on the carrying wagons, which was a second weak point, has proved quite effective, and there have been no mishaps with it either during journeys or during shunting and marshalling operations. The operations of transhipping proper allow of the exchange of 6 wagons, or, say, 60 tons, per hour, at any exchange point, with a staff of two labourers. The economy in labour thus effected is sufficient to pay off within about two years the whole of the capital invested in providing the wagons and equiping the exchange station.

Elevation.


A l'axe du tampon = 1,050
A l'axe de la trav. de tête = 1,052 5
Rail
Rail

Plan.

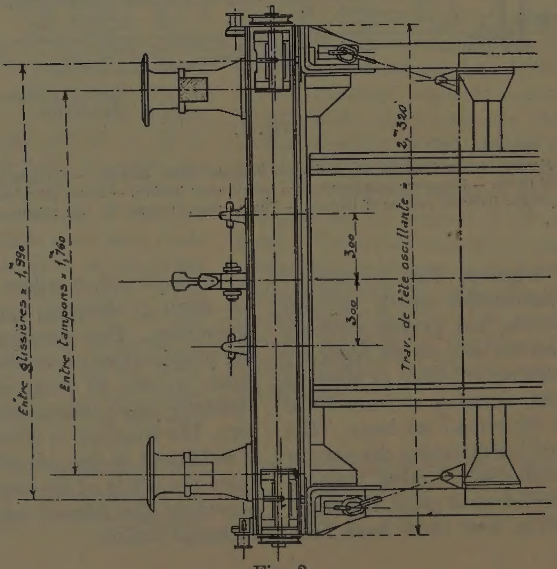


Fig. 2.

Explanation of French terms : A l'axe du tampon = To centre line of buffer. — A l'axe de la trav. de tête = To centre line of headstock. — Entre glissières = Between guides. — Entre tampons = Between centres of buffers. — Trav. de tête oscillante = Pivoted headstock.

The system above described doubtless could not be applied integrally everywhere, no matter the conditions. It is only presented here as a solution that has been found satisfactory in one particular case. It is, however, capable of rendering service such as described above, when the distance between the exchange point and the loading point is not too great, and when the daily tonnage is sufficient to allow of a rapid amortisation of the capital expended, a double condition frequently found in coalfields and ports.

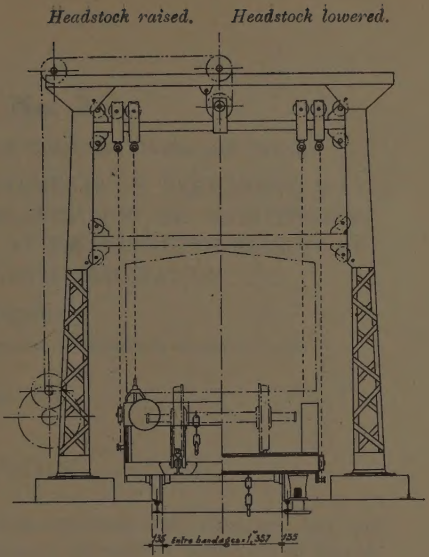


Fig. 3. — Side view.

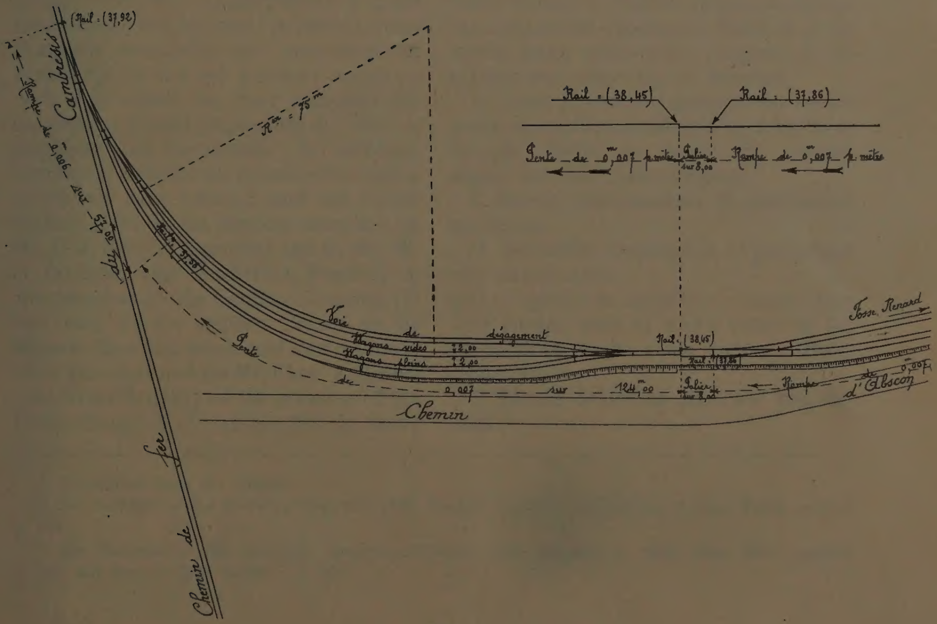


Fig. 4.

Explanation of French terms : Chemin de fer du Cambrésis = Cambrésis Railway. — Pente de 0m007 p. mètre = Down gradient of 1 in 142. — Palier = On the level. — Rampe de 0m007 p. mètre = Up gradient of 1 in 142. — Voie de dégagement = Switching track. — Wagons vides = Empty wagons. — Wagons chargés = Loaded wagons.

[625 .172 & 625 .173]

REPORT No. 2

(America, British Empire, Holland and Colonies, China and Japan)

ON THE QUESTION OF RECENT IMPROVEMENTS IN PERMANENT WAY TOOLS, AND IN THE SCIENTIFIC ORGANISATION OF MAINTENANCE WORK (SUBJECT IV FOR DISCUSSION AT THE ELEVENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION) (1),

By Ch. H. J. DRIESSEN,

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Figs. 1 to 32, pp. 387 to 413.

INTRODUCTION.

The subject covered by the title of this Report has already been considered at both the Rome (1922) and the London (1925) sessions. Consequently a great resemblance will be found in certain questions on comparing the questionnaires drawn up for the two previous enquiries with that which has been compiled for the present Report (Appendix A); this is, moreover, not surprising. In addition, however, a comparison between the replies which we have received and the information given in the Reports compiled by Mr. G. J. Ray (for America) and by Mr. W. H. Coomber (for the British Empire) on the occasion of the London Congress (2) and even in the Reports drawn up by Messrs. Epes Randolph and Earl Stimson (for America) and by Mr. Chas. J. Brown (for Great Britain) on the occasion of the Rome Congress (3), shows that in many Administrations the situation has not changed appreciably, especially as regards scientific organisation of permanent way maintenance; as regards improvements in the mechanical appliances, there is at all events some noteworthy progress to be pointed out, especially in America.

In order to obtain a general idea of the questions under consideration, it has been thought useful to divide the subject matter into two main chapters :

I. Recent improvements in mechanical appliances,

II. Scientific organisation of permanent way maintenance,

and to subdivide these two chapters into four groups, each of which refers as far as possible to the same factors. These groups are :

1. United States of America and Canada.

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(1) Translated from the French.

(2) See *Bulletin of the Railway Congress*, 1925, January number, (1st part), p. 1, and March number p. 675.

(3) See *Bulletin of the Railway Congress*, October 1920 number, p. 665, June 1921 number, p. 663 and August 1921 number, p. 977.

2. Great Britain and Ireland.
3. South America, India and the British Colonies, the Dutch Colonies, China and Japan.
4. Holland, to which is devoted a special position owing to the nationality of the Reporter.

The appendix B will enable the reader to form some idea of the importance of the information contained in the present Report. Since, moreover, we find that 52 %, representing 70 % of the total length of railways belonging to the Administrations consulted have replied, it may be said that the Report is based on information of a sufficiently wide character.

CHAPTER I.

Recent improvements in mechanical appliances.

United States of America and Canada.

Machines for picking up the track.

Several Administrations have replied in the affirmative to the question concerning these machines. They have, however, had in mind the appliances for breaking up and removing the ballast such as will be described in dealing with the question 1*n* : *Weeding and cleaning the ballast.* The machines which question 1*a* was intended to cover were those employed solely for clearing the formation of the rails and sleepers and the ballast. Such machines are built with the object of renewing the rails and the sleepers as a whole; they are not merely used to clear the formation but also to lay the new track (see below Question 1*e* : *Removal and laying of completely assembled portions of track*).

It should be stated that special machines for removing the track are not employed, but that the machines coming within the scope of Questions 1 *b*, *c*, *f*, *i*, *k*, and *n* are also used to strip up from the permanent way its constitutent parts.

Loading, transporting, and unloading ballast.

The use of mechanical appliances for loading, transporting, and unloading ballast is very general (only two administrations have replied in the negative).

Loading takes place at the quarries, by means of loading hoppers, directly into the wagons which in certain cases are self-discharging, specially built for transporting ballast. In one other case, coal wagons are used or even ordinary wagons (in which case, the wagons are unloaded by means of a grab).

It does not appear necessary to describe the different types of self-discharging wagons. Some of these are wagons with a hopper discharging at the bottom or at the sides, others have tipping bodies or drop sides.

Where travelling cranes with a grab for unloading the ballast are employed, it is necessary to have two tracks available, one for the ballast train, and the other for the crane. Obviously on many railways, such conditions are not easily to be found.

One administration makes use of a special device for unloading — a ballast distributor, of which some idea may be gained from figures 1 and 2. It consists of a sheet metal receptacle secured by means of chains which may be tightened by levers, below the hoppers of a large wagon in such a manner that the small grooved wheels of the distributor rest on the track. The distributor is provided with adjustable openings both in the bottom and at the sides. It is not customary, as figure 2 shows, to attach two distributors under one wagon, the single distri-

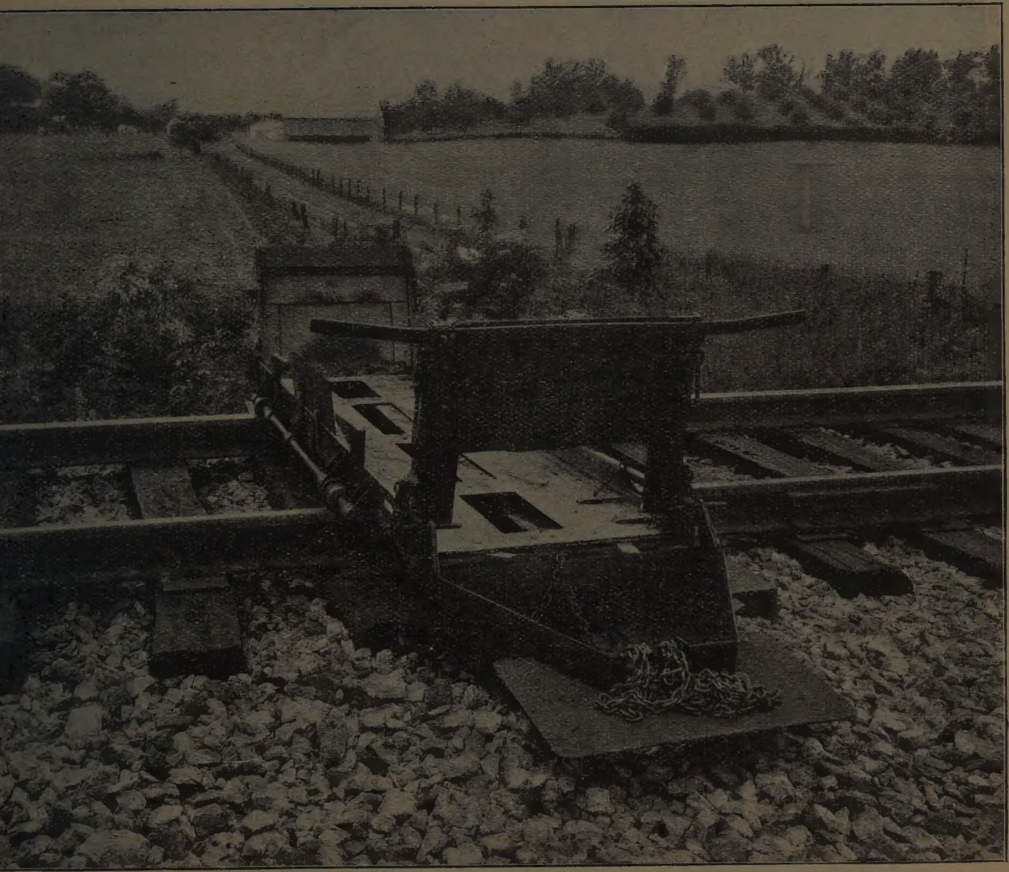


Fig. 1.

butor required for each wagon being placed under the other hoppers when the wagon is half emptied.

Another administration unloads the ballast (which is loaded in low sided wagons with drop sides) by means of a kind of plough, called the « Lidgerwood » drawn by a powerful steam winch. Figure 3 gives a general idea of this device. The steam winch is mounted on a special truck coupled immediately behind the locomotive, so that the latter provides the steam for the winch. When unloading is started, the plough is at the back of the train. The cable is unwound by attaching it to any fixed point, while

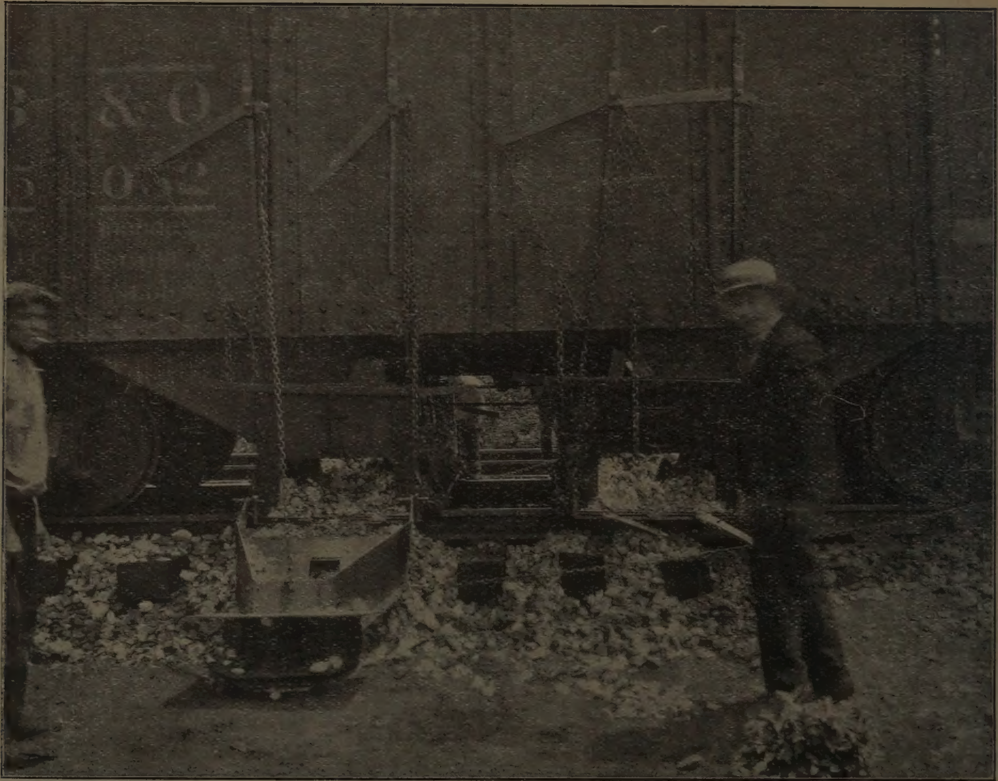


Fig 2.

the train moves ahead, until the plough has arrived at this point, when the plough is attached to the cable. After removing the sides of the wagons along one side, and on starting up the winch, the plough is drawn forward, pushing the ballast in front of it, the ballast being unloaded by the action of the sloping front of the plough. The side of the plough is constructed so as to slide along the wagon stanchions without the nose catching in them. When unloading on a curve, the cable is passed over guide pulleys fixed to the stanchions and which maintain the cable in its place.

As regards the cost price, the information is so indefinite that it cannot be considered worth mentioning here. To give an approximate idea it may be stated that the price of a 30-ton travelling crane is $ 15 000, and that of a 15-ton travelling crane is $ 10 000.

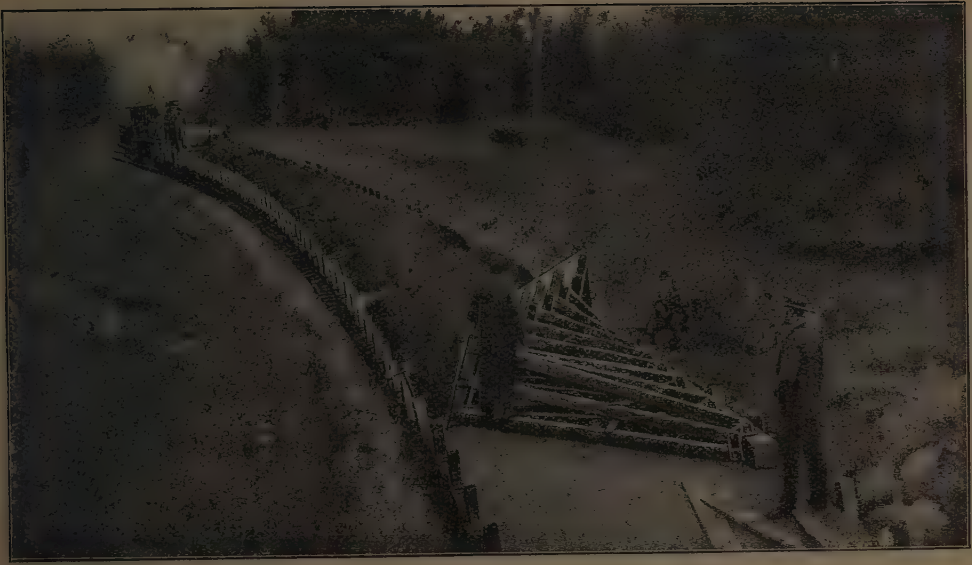


Fig. 3.

As regards the working expenses for locomotive cranes, the replies received do not enable any figures having any value to be given. Some administrations have not given any figures at all, others mention annual or daily expenses, without indicating the amount of ballast unloaded. As regards the ballast distributor alone the cost price of which is $162.50, it is said that the cost of unloading 50 tons (± 32 cubic yards) of ballast is $4 to $15, and $7.60 on the average, and that the cost of unloading and laying the ballast was, for the same quantity, $50 before the distributor was used and $25 afterwards, *i.e.* a saving of 50 %.

Although not generally confirmed by figures, the administrations are unanimous in their opinion that the saving is very appreciable, and that in those cases where it is not so (for example owing to very heavy traffic necessitating relaying the track in the rather short intervals between the ordinary trains) the time required to unload a ballast train is reduced to such an extent, that this alone justifies the use of special appliances. Of course, as wages increase, the economic savings also increase, whilst another advantage is that the work is done with less effort on the part of the workmen, who are thus the better disposed to carry on with their work.

The cranes are generally steam driven. The number of men required to operate a steam crane is two — a driver and a fireman. As regards the other men required for carrying out the other jobs in connection with the unloading of ballast, the information received does not permit of any definite figures being given. A crew of 9 men including the foreman is required to work the ballast distributor. These 9 men do all the work necessary for unloading the ballast.

Loading and unloading rails and ballast.

Several railways have the rails sent direct from the rolling mills to the sites where they are to be laid, in which case it is merely a question of unloading; if rails are to be loaded from the track, that is to say rails that are being replaced, the same machines are used for this as for unloading the new rails.

All the administrations that have replied to the questionnaire employ machines for unloading the rails, either the same cranes which are used for other work, or special cranes which in this case have a long jib so that they can be placed on the same track as the trucks carrying the rails.

Generally the rails are taken up one by one by means of rail tongs attached to the crane hook. In one case reported the rail is lifted by means of an electro-magnet.

Figures 4 and 5 show a special wagon on which are mounted two cranes with movable frames, or « derricks », having a lifting capacity of 10 tons. The source of power is a petrol engine. When employed on the permanent way, the wagon is formed in the material train; the cranes are in the position shown in figure 4, while figure 5 shows the cranes in use. It should be noted, and this also applies to locomotive cranes, that when there is only one track available, it is necessary to make a shunt after unloading two wagons, which generally involves returning to a station. This does not necessarily imply a delay in unloading for it is very probable that the train service will not allow more than two wagons to be unloaded without interruption. If two tracks are available, which can be more easily the case on 4 or 6-track lines, the locomotive portable cranes are able to move the full length of the lines alongside the train. In the case of the special wagon, it can probably be worked by hand along the train.

A crane which is used not only for loading and unloading rails, but which is also of universal use, is the « Burro » crane, an example of which, mounted on a small wagon with small wheels, is shown in figure 6. This is a portable crane driven by a petrol engine. When an electro-magnet is employed for dealing with steel materials, a generator is added to the power unit. A design of this type of crane is also employed wherein the small wagon can be displaced on two rails fixed to the bottom of a bogie wagon.

As regards the saving effected, one administration states that, in unloading rails by means of a crane (special crane driven by compressed air) the cost is $0.82 to $0.72 per ton, depending upon whether the rails are loaded on wagons with or without sides, whereas previously, unloading by hand cost $1.12 per ton. Another administration, for the purpose of comparison, gives the cost of unloading new rails, laying these rails, and loading up the old rails (steam crane) as $5 per ton while the same operations without mechanical appliances required an expenditure of $15 to $20 per ton. Most of the other administrations vouchsafe the information, without giving figures, that in their opinion the saving is considerable when cranes are employed for unloading rails.

In addition to the above advantages it has been found that the use of such equipment results in others namely : there are fewer accidents; the rails are not damaged and particularly the ends of the rails are not bent; the work requires less men, so

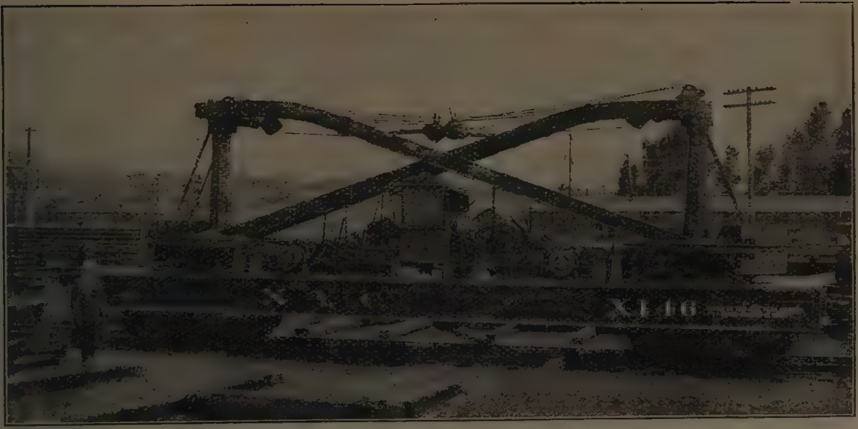


Fig. 4.

that it is unnecessary to collect at a given spot so large a number of men, some of whom may have to come long distances; the work is completed more rapidly.

Sleepers are generally loaded up in the creosoting sheds, either by hand or by suitable appliances. With the exception of one administration, which uses a special crane for this purpose, sleepers are unloaded by hand. If the sleepers are loaded on flat-bottomed wagons or wagons with movable sides, they can be easily unloaded by sliding them off on to the side of the permanent way. Two administrations carry the sleepers in ordinary wagons to a station and distribute them along the permanent way by means of tractors and trolleys.

Fig. 5.

Spreading and rolling the ballast.

The ballast is generally spread as well as possible by employing self-discharging wagons, the distributor or cranes, and so using them that the ballast is deposited where necessary. For spreading ballast in those places where too much may have been unloaded, it is a very general custom to attach to the wagon, in front of the wheels, a sleeper or a plank at the level of the rails so that as the wagon moves forward, the ballast is pushed forward and sideways. Mechanical appliances are not employed for spreading, the work being generally completed by hand with forks and shovels.

Rolling of the ballast is not practised in America. It is believed that this may be attributed to the manner in which the permanent way is renewed, that is to say, it is unusual for the sleepers and rails to be renewed together, as the sleepers are renewed one by one as required, and new rails are laid on the sleepers just as they happen to be in the track. The Reporter believes, however, that rolling in the bed of ballast would be of paramount value and have a considerable effect on the state of the track and the maintainance costs especially in those instances where it attains a depth of 30 cm. (1 foot) or more. If the ballast ever had to be removed completely from the track, in the Reporter's opinion, rolling in the ballast would be worth while considering.

Unloading and laying completely assembled portions of the track equipment.

Since, according to what has been said in the preceding section, a complete renewal of the track (out of face renewal) is not practised, it follows that no mechanical appliances are employed for effecting such a renewal of portions of the permanent way. (One administration points out that the staggered joints used on its tracks would, moreover, be against this method.) It is only when special parts of the track have to be renewed, such as points, crossings, etc. that some administrations employ cranes for removing the old portions of the track equipment, and laying the new portions. The old portions are lifted by means of travelling cranes and removed to a place where they can be easily taken to pieces, while the new portions, assembled in a suitable place, and brought into position, are laid in the track by the cranes. Figure 7 shows slip points suspended from the hooks of two travelling cranes.

Transport of material along the track.

The transport of material, with the exception of ballast, is most usually effected by means of ordinary wagons, which during loading and unloading are marshalled in a special material train. In this way the material can be transported over long distances without difficulty, the wagons when unloaded afterwards being attached to ordinary trains.

Several companies mention the fact that material is also transported by means of tractors driven by petrol engines to which are often attached several small wagons of a special type. It is evident, of course, that this arrangement does not enable the material to be carried long distances. It would be interesting, therefore, to know for what distances this means of transport is employed, but unfortunately the information received throws no light on this matter.

For short distance transport, for instance within the length covered by a gang, hand-propelled trolleys are used, while for removing small quantities of material a vehicle called the « Pony car »

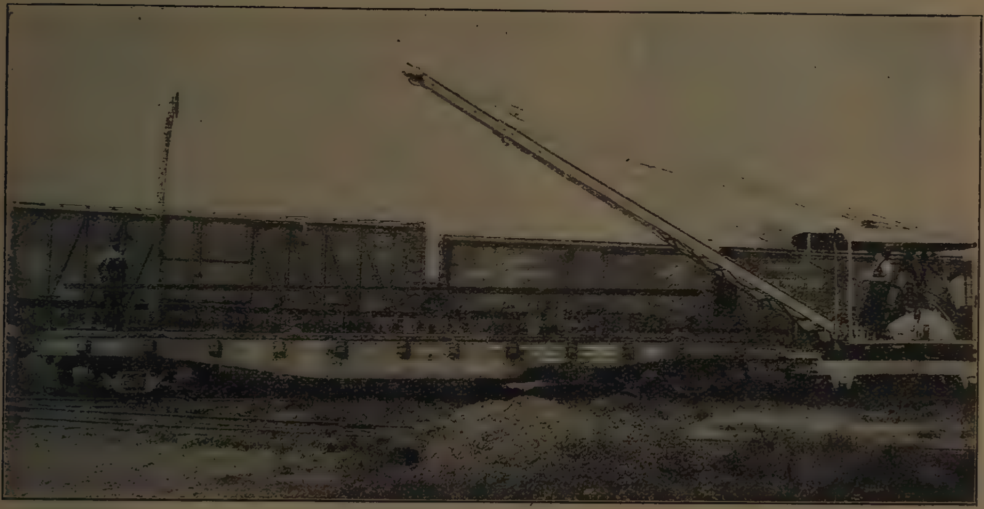


Fig. 6.

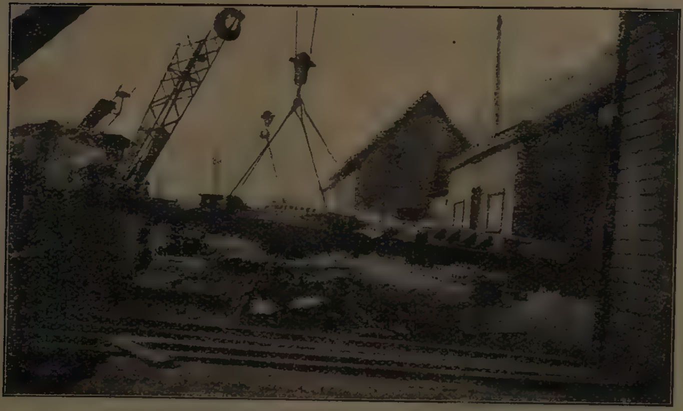


Fig. 7.

for the large pattern, and « Dandy car » for the small pattern, is very useful. Although very few administrations mention this vehicle it is presumably very extensively used. As shown in figure 8, which represents the smaller pattern, the device is a small monorail truck which is easily balanced by one man. It is easy to load 2 000 lb. per pony car and 1 000 lb. per dandy car, either in rails (two cars are employed for long rails, or in sleepers, or if material, such as spikes, bolts, or small quantities of ballast, is to be moved, a box is placed on the frame of the car. One great advantage of this car is that if the line has to be cleared unexpectedly, it is only necessary to tip the pony car so that the load is deposited outside the track, when the car may be removed. This feature is above all very useful in moving material about in stations.

There remains to be mentioned the fact that one administration, for the purpose of distributing part of the material to be laid and to collect that which has been taken up, runs every month a special train made up of different types of wagons, some provided with boxes, planks, etc., and divided into compartments with the view of keeping the different kinds of material separate. This practice has been in use for 15 years.

Drilling and adzing sleepers.

Of the 13 administrations who replied to the questionnaire, 8 do not prepare the sleepers before laying them in the track. One gives a reply in the affirmative without indicating, however, how the sleepers are drilled and adzed, while 4 administrations have these operations carried out at the creosoting shed, before impregnation of the wood. It has been thought unnecessary to give a description of the machines for drilling and adzing sleepers, these machines being well known. It may merely be recalled that these machines, working continuously, afford considerable advantages as compared with manual labour, while by carrying out the operations of drilling and adzing the sleepers before impregnation, the life of the sleepers is obviously affected, the layer of preservative not being damaged by any drilling or adzing after the sleepers have been laid in the track.

Since in America mild steel sole plates are generally employed, the adzing of sleepers is not so necessary as in the case where cast iron rail chairs are employed. Still, as has already been mentioned, the previous drilling of the sleepers has advantages from the point of view of the life of the sleepers.

Distributing and laying sleepers. Laying rails.

The sleepers being unloaded close to the place where they are to be used, there is no necessity for them to be distributed beforehand. The sleepers are laid without exception by manual labour alone.

It is different as regards the rails, which are laid in almost all cases by mechanical means. Only one of the large companies was satisfied up to recently to use manual labour, but this company has now begun to make a trial with special equipment.

The majority of the administrations employ a locomotive portable crane for laying the rails. This crane runs on the track, the rails of which are to be renewed, and it therefore removes the old rails, lays the new rails, and, when the rails have been joined up, moves forward on the new track. The cranes employed for this work are either cranes which are also used for other purposes, or are special cranes in which case their power is small.

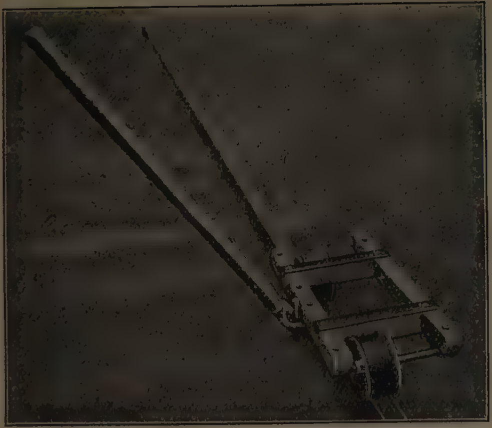


Fig. 8.

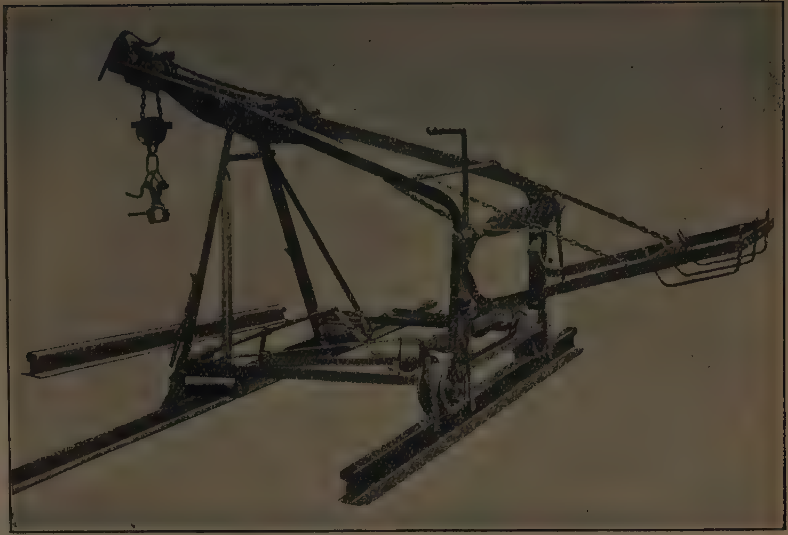


Fig. 9.

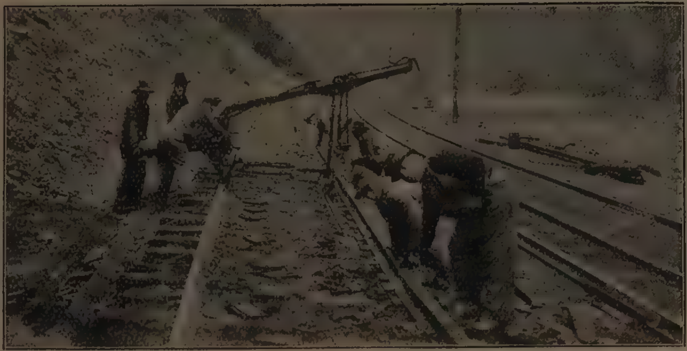


Fig. 10.

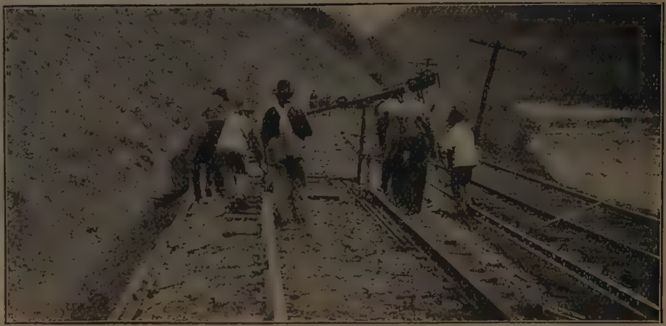


Fig. 11.

Most of the companies using cranes merely state that a considerable saving has been effected by their use. In one case it is said that unloading the new rails, laying them, and loading up the old rails with a steam crane costs $5 per ton while manual labour would cost $15 to $20 per ton. Another administration says that a large special travelling crane for laying rails does the same work as 20 to 24 men.

An appliance described in Mr. G. J. Ray's Report for the London Congress (*Bulletin of the Railway Congress*, January 1925 number, p. 6), has become very extensively employed, according to the information received. This appliance, a sketch of which will be found on the page referred to, and of which figure 9 is a photograph, is called the «Three man rail layer» or « Madden rail layer ». The appliance consists of a frame fitted with a winch with chain, pulley and rail tongs, carried on four wheels, two of which are grooved and run on one of the track rails, while the other two run on a short length of light rail. By means of a balance weight in a holder at the back, the machine may be maintained more or less in equilibrium on the track rail, so as to free the length of light rail. Figure 10 shows the appliance at the moment of laying the rail, which has been picked up by the rail tongs from the spot alongside the track where it was placed after unloading. Figure 11 shows, the appliance moving forward, the length of light rail being released so as to be drawn forward.

When the appliance is fitted with wide rollers as shown in figure 9, the piece of light rail may be discarded, the machine then resting on the old rail which is displaced for this purpose towards the centre of the track.

The first cost of a « Madden rail layer » is $425. One of the administrations has worked out the cost per mile of track to be $21.60, while manual labour with rail tongs cost $57.60 per mile of track. By means of the Madden rail layer the same work is performed by 5 men in less time and with less fatigue, as by 15 men using ordinary rail tongs.

Another administration employing the Madden rail layer fitted with a petrol engine, which is said to be as easy to operate as a machine without engine, gives a saving of 60 % which agrees very well with the other figures. Four men are employed per machine.

A third railway says that with the Madden rail layer, 7.22 feet are laid per man-hour, while for manual labour 6 feet must be reckoned, which is a saving of 20 %. The machine tended by 3 men does as much work as 12 men without machine.

Driving the coach screws of the chairs or sole plates into the sleepers.

The question being restricted to fixing by means of coach screws, excluding spikes, most of the administrations have given a negative answer, the general practice in America being to employ sole plates fixed with spikes. Neither coach screws nor chairs are used.

Some railways state, however, that they make use of spikes which generally are driven home by manual labour, with the use of a hammer. Two administrations use compressed air hammers for this purpose, while another mentions that it is the intention to carry out trials with a mechanical appliance.

One of these two administrations has employed, since 1927, the compressed air tool, of which figure 12 shows a photograph. The price of this tool is $195. The saving has not yet been determined. It is believed to have been found, however, that, when long lengths of track have to be laid, much time is gained by employing a man to go in front of the tool, who places the spikes in position by means of a slight blow of a hammer, the tool following him up, and driving the spikes completely home. It is expected, also, that with this tool, the spikes will be driven in straighter and more regularly than by means of the set-hammer.

Tightening the bolts.

In America only the tightening of the fish plate bolts of the rail-joints has to be considered. On the majority of the railways this is done by manual labour. One administration employs a compressed air appliance in special cases which are not specified but which probably arise when long lengths of track are to be renewed and when an air-compressor employed for other work is available.

Another railway has been using a compressed air tool since 1920, both for unscrewing the bolts and for tightening them. It is stated that, for a joint with 6 bolts, the bolts are put in position and tightened in 30 seconds, the compressed air tool tended and accompanied by 5 men doing as much work as 30 men with spanners.

One railway, which has been making trials since 1929 with the compressed air tool shown in figure 13, the price of which is $390, says that the appliance is not able to tighten the bolts sufficiently, the lack in tightness having to be made up by means of ordinary spanners, an operation which makes it doubtful whether any saving can be effected.

Reference should also be made to a remark made by one administration, that it is not in favour of the use of mechanical appliances for tightening the bolts of rail joints, it being more economical to put the bolts in position by means of small spanners and tighten them afterwards by means of long spanners. The greatest objection to compressed air appliances is that they do not tighten the bolts with as much force as the ordinary spanners. The length of these spanners is as follows:

Fig. 12.

For 1 3/8 inch bolts : 4 feet 2 inches.
For 1 1/8 inch bolts : 4 feet.
For 1 inch bolts: 3 feet 6 inches.

The Reporter would like to point out that, considering above all the fishing-angle usually varying between 14° and 18° which corresponds to a slope of 1 : 4 and 1 : 3, the fishplates would be clamped so tightly to their seats by spanners of such length, that it would be quite impossible for the ends of the rails to expand. In the humble opinion of the writer, it would be better not to tighten the bolts so much, but to employ an intermediate piece to act as a spring (for example, Grover washers).

Levelling the ballast.

There are only three companies employing mechanical appliances for levelling the ballast, and one other making use of such appliances to a limited extent. The machine employed by all these companies is the « Jordan spreader », a powerful machine comprising essentially a heavy truck provided with adjustable wings, the truck being hauled by a locomotive.

The Jordan spreader is a machine which is not solely or primarily employed for levelling the ballast; it is chiefly employed for making the ditches and banks, principally of the railways and other roads under construction. A few dimensions will serve to provide some idea of the power of this machine, which is shown in figure 14 in the act of shaping the ballast, the side and the top of the bank.

	Old pattern	*New pattern*
Total weight . . .	85 000 lb.	115 000 lb.
Length of machine .	35 feet	50 feet
Maximum radius of wings	21 ft. 6 in.	24 ft. 3 in.

The new pattern has its centre of gravity 40 % lower than that of the old pattern, and the wings may be displaced while the machine is in action (by means of a telescopic arm actuated by hydraulic power), so that fixed obstacles may be passed.

A kind of plough placed in front of the machine, and of which the lower edge extends to half an inch above the upper face of the sleepers, makes it possible to clear the ballast almost entirely from the face of the sleepers.

One company quotes $20 000 as the price of a Jordan spreader. No information is provided either as regards the maintenance costs or the savings effected. It is evident, however, that a machine of such power can only be economical if it is used continuously for all kinds of work, over a sufficiently long period and over long distances. There will be occasion later on (Chapter II) to refer to the Jordan spreader as employed for performing other work in connection with the maintenance of the permanent way

One of the three administrations employing the Jordan spreader also makes use of another machine known as the « Track skeletoniser ». According to the information provided, this machine is only employed for levelling the ballast. The machine is portable and is represented in figures 15 and 16. By means of small wheels on its sides, it may be removed from the track and placed on the berm. The machine, which is fitted with a petrol engine, costs $5 000 and the running expenses are $0.06 per space between two sleepers, that is to say, considering the distance, 1 franc per foot, which in the opinion of the writer, is a very high price for this work.

Straightening and levelling the track.

Most of the administrations have replied to the effect that they do not employ mechanical appliances for straightening and levelling the track. It is probable, however, that all or nearly all the companies make use of the small tools referred to in several replies, that is to say,

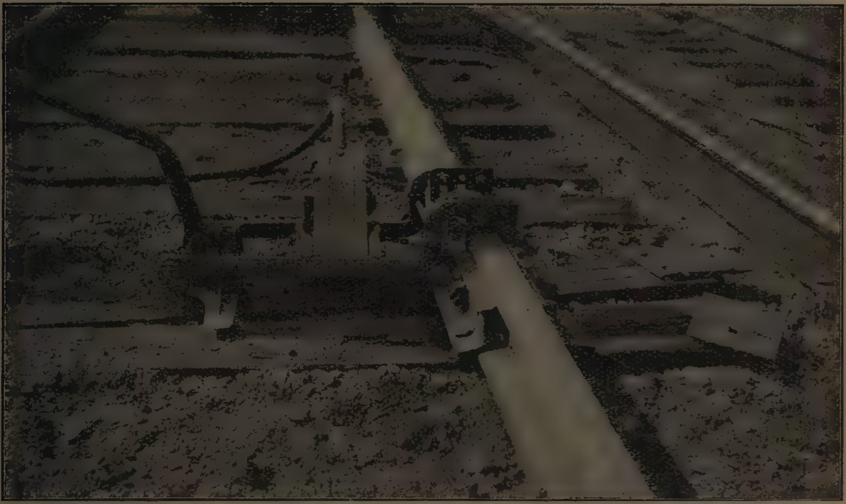


Fig. 13.

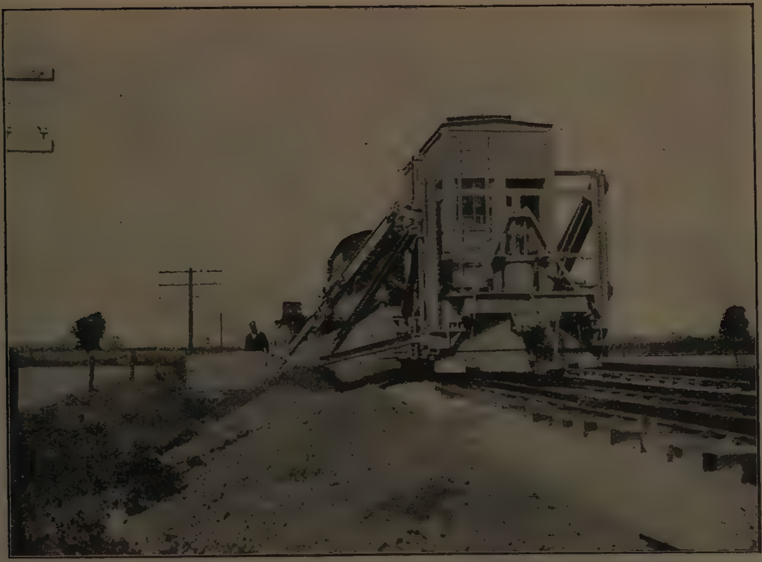


Fig. 14.

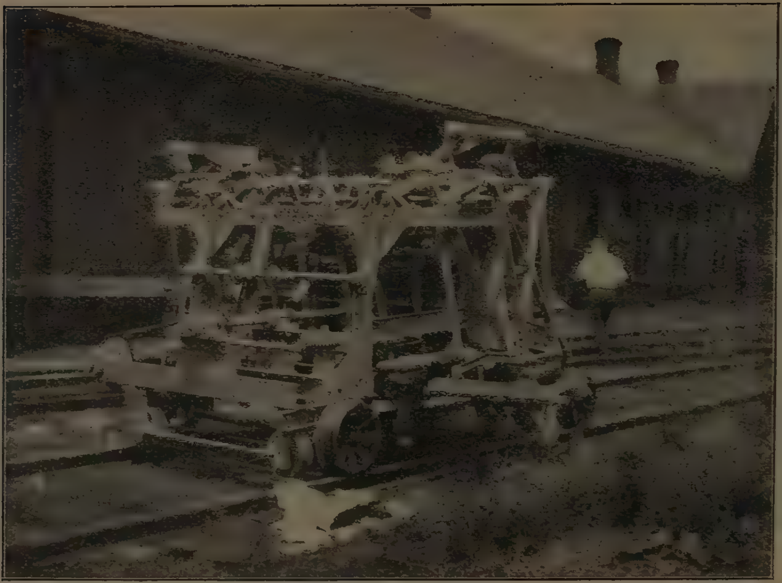


Fig. 15.

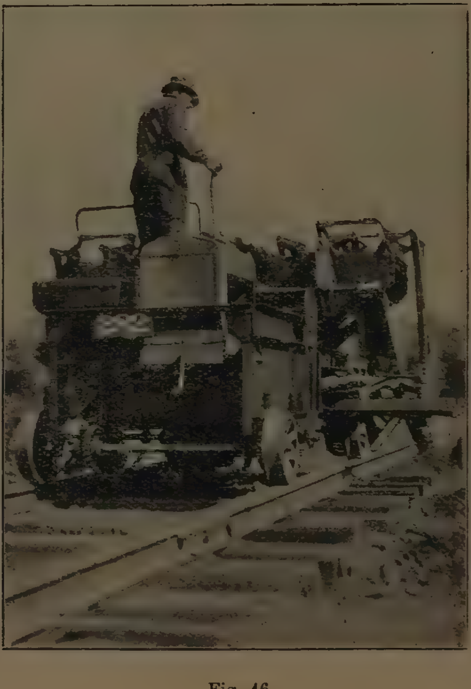


Fig. 16.

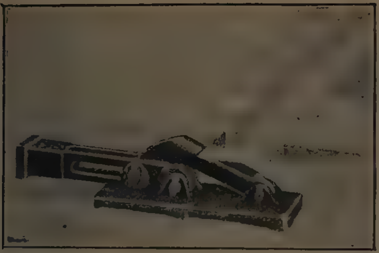


Fig. 17.

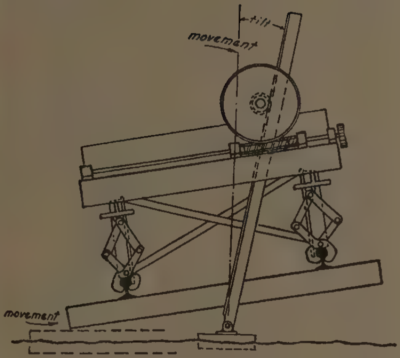


Fig. 19.

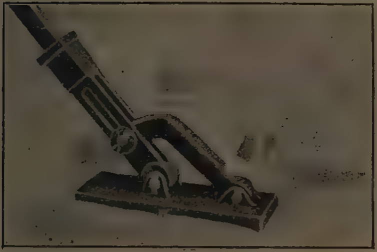


Fig. 18.

Fig. 20.

tools for lining up the track and jacks for lifting it. The latter are generally known, but the former are less extensively used. Figures 17 and 18 show the tools in use for lining up the track. It is evident that by means of this tool, the lining up of the track is performed more easily than by means of straightening bars; it is stated that 2 men, employing this tool, can do the same work as 7 men without it. The price of this tool varies between $7.50 and $12.

A special machine for lining up the track that is mentioned in a catalogue sent by one administration, which does not state if it makes use it, is shown diagrammatically in figure 19. A small truck mounted on 4 small wheels may be fixed to the track by means of 4 clamps. A rack, provided at its lower end with a shoe, rests in an inclined position on the ballast, so that when the machine is operated (petrol engine) the truck and the track are raised as a whole, and at the same time displaced laterally, As the lining up of the tracks in service as a rule only involves a small movement, it is only possible to use the machine for the maintenance of the permanent way in exceptional cases. When, however, it is a question of doing earthwork, the machine may render useful service. Its cost is $4 000.

Packing the ballast.

Of the 13 administrations who have replied, there are three, two having a very short mileage, and one an average, who pack the ballast by hand with picks, while the largest company of the three replies that very few mechanical packing tools are employed, the packing being generally done by hand.

The remaining 10 companies pack the sleepers by means of mechanical tampers, usually driven by compressed air; two railways use electrical tampers as well as compressed air appliances.

The plant always includes a power unit which may be moved along the track, but which, during use, is moved away from the track on small side wheels. Figure 20 gives an idea of the general arrangement.

When compressed air tampers are employed, the power is given by a petrol engine with air compressor and air tank; usually the plant is powerful enough to supply 4, 8 or 12 tampers. The prices quoted vary, but on the average are $3 000 for a 4-tamper machine, $4 000 for an 8-tamper machine and $5 000 for a 12-tamper machine. The price of a tamper is $125 to $200.

As regards the saving effected, one administration states that a foreman with 11 men provided with 4-tampers can do as much work as four times the number carrying out the work by hand. Another, employing for a unit of 12-tampers, a staff of 20 men, has worked the expenses out to be $ 0.15 per foot of track, which is equivalent to 60 % of the cost of manual labour. A third company employing the same equipment, states that the expenses vary between $0.0925 and $0.1104 per foot of track, which is less than half the cost of manual labour.

The source of energy of the electric tampers comprises à petrol engine with dynamo; the weight of the entire outfit is such that it can be lifted by 6 to 8 men and placed on the rails and moved along on two small grooved wheels. The generator produces current at 110 volts with an output of 7 kilowatts at 1 500 revolutions per minute. The cost price of an outfit of 4 tampers is $2 500. Eight men are necessary to attend to the power plant and the 4 tampers. The working expenses are $0.08 per sleeper end or $0.16 per sleeper, while packing by hand requires an expenditure of $0.20 per sleeper, so that a saving of about 20 % is effected. Since the source of power is very portable, the machine can be used for packing lengths of 200 feet upwards.

The information received regarding the distance which may be covered without having to move the power plant differs considerably. While one administration claims that the tampers may be used up to 3 200 feet from the power plant, another does not employ air mains longer than 750 feet. For the electric machines it is said that this distance is from 300 to 600 feet. It is no doubt owing to the ease with which the electric source of power can be displaced that for the latter the distance to be covered is less.

In addition to the saving, the sleepers can be better packed by using mechanical rammers, with the result that the track can be left longer without requiring any attention, while fewer men are required to do the same work than in the case of packing by hand (one of the replies states that the number is 40 % less).

Weeding the ballast.

It is obvious that the machines used for cleaning the ballast also effectively weed the ballast at the same time. In this chapter, however, those machines will be considered that are only suitable for weeding as such, that is to say, machines for destroying or pulling up the weeds. This includes chemical processes, burning the weeds, or the use of mechanical weeders.

According to the thirteen replies which have been received it follows that five companies do not employ any special appliances for weeding the permanent way, while the use made of the special processes is as follows :

Burning the weeds . .	1	1		1
Chemical process . . .	2		1	
Mechanical weeder . .	2			

The chemical process is applied by spreading a liquid destroyer by means of sprinklers connected with a supply tank, the whole being placed on a small rail motor vehicle or on a wagon hauled by a vehicle of this type. No indication is given as to the chemical product employed. The working costs vary between $24 and $38 per mile.

The burning of the weeds is generally effected by blowing on to them very hot gases. Figure 21 shows a contrivance comprising a tank wagon, containing the oil, a second wagon fitted with a petrol engine driving a blowing machine, and a third wagon carrying a large dome-shaped vessel, lined with fireproof material, and under which are located the burners. The price of such an outfit is $3 500. One administration gives the price of a more powerful outfit as $8 000. The running expenses vary between $6 and $9.30 per mile. It would appear that it is necessary to pass over the same length twice.

Mechanical weeders generally work outside the sleepers. Only one administration mentions a machine which pulls up the weeds inside the track, but does not give any detailed information. The same company makes use of the machines for levelling the ballast, known as the Jordan spreader, for weeding outside the sleepers, by fixing teeth to the wings. As for the remainder, either special wagons provided with teeth mounted on a movable structure, as shown in figure 22, are employed, or a special automatic machine is used, an example of which is shown in figure 23. The price of machines of this type de-

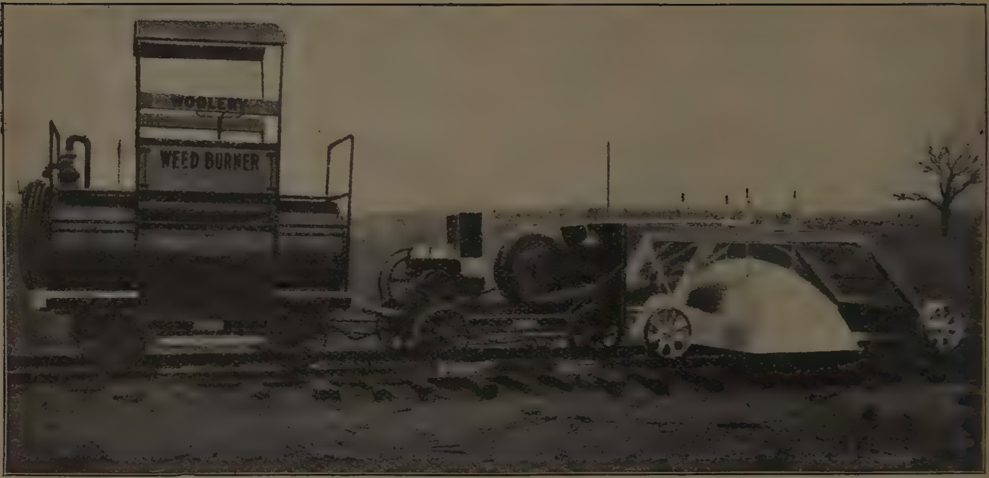


Fig. 21.

pends upon their power, which varies greatly. That of the machine in figure 23, for example, is $1 175. The working costs are found to vary between $1.40 and $3.50 per mile. It depends upon the amount of weeds whether the same track is gone over once or several times in a season.

One administration says that manual labour requires an expenditure of $5.7 per mile; another only mentions a price of $6 to $8 per mile, figures which can only be noted with some surprise.

A secondary advantage of mechanical weeders, which is not indicated but which the writer, however, considers important, is that the teeth in working the bed of ballast and the berms outside the sleepers facilitate in an effective manner the drainage of water.

Cleaning the ballast.

Four companies use mechanical appliances for cleaning the ballast; one employs cranes with a grab which deposits the ballast on a wagon fitted with a screen; two make use of of an appliance known as the « McWilliams Mole », and the fourth makes use of both devices. In both cases it is necessary to deposit the whole of the ballast to be cleaned in the space between the tracks; this removal of a portion of the ballast is done by hand; one of the companies utilises, however, a kind of plough hauled by a locomotive to remove the bed of ballast outside the sleepers.

Figure 24 shows the plant consisting of a steam crane and grab with a wagon with screen. The ballast after being cleaned, falls on to the track again behind the train, while that which passes the screen is collected in the wagon itself. The cost of cleaning a cubic yard of broken stone ballast is $0.31 using a train with one crane, and $0.18 when there are four cranes.

Fig. 22.

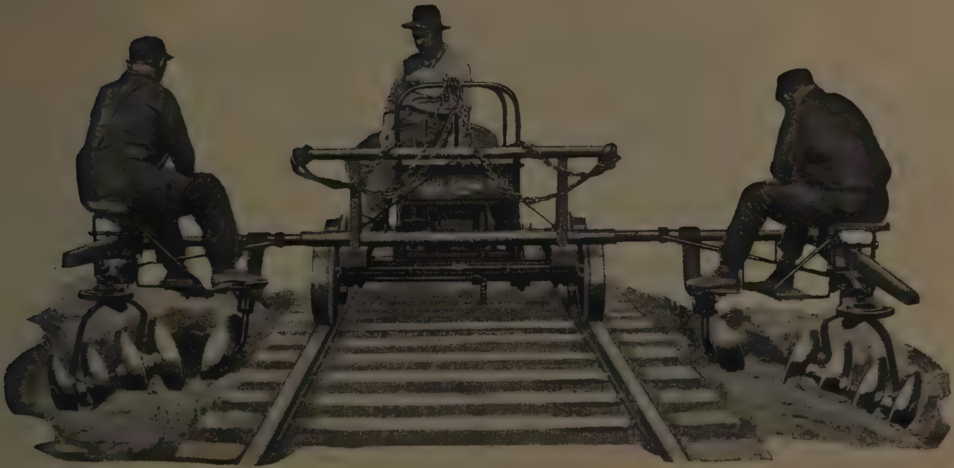


Fig. 23.

Another company gives the costs with a similar plant as \$0.297 to \$0.452 per cubic yard. In addition to the train staff, a driver, a stoker, a foreman and two men are required (the men necessary for throwing the ballast into the six-foot are probably not included). It is assumed that in a season the cranes work the equivalent of four months and that they clean 10 miles of double track.

The « McWilliams Mole », of which figure 25 shows the principle and figure 26 gives a photograph of the appliance at work, comprises in the first place a 15-H.P. petrol engine, followed by a nose *a* inclined at an angle of abcut 45°. which burrows in the ballast. On the inclined nose are located two teeth of manganese steel, which, actuated by a disc, act as scrapers and thus bring the ballast

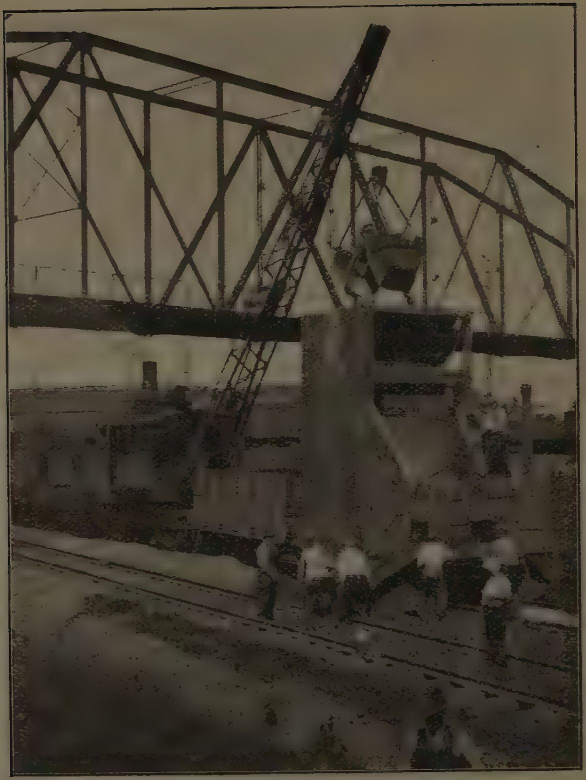


Fig. 24.

on to a conveyor belt *b* whence it falls on to a screen *c*, to which is given a rapid motion in both a horizontal and a vertical plane. The cleaned ballast is directed on one side and falls into the space between the tracks, while that which passes the screen is deposited on another conveyor belt *d* and passes into a steel receiver placed at *e* which is changed each time it becomes full. The appliance moves forward under its own power; for this purpose longitudinal racks *f* are placed on the end of the sleepers and wedged against the web of the rails; the front rollers *g* resting against the racks while the back rollers *h* are provided with teeth. The appliance is constructed entirely clear of the maximum loading gauge so that it may remain in operation during the passage of trains.

The price of the plant is $8 000. The operating expenses are $0.34 per cubic

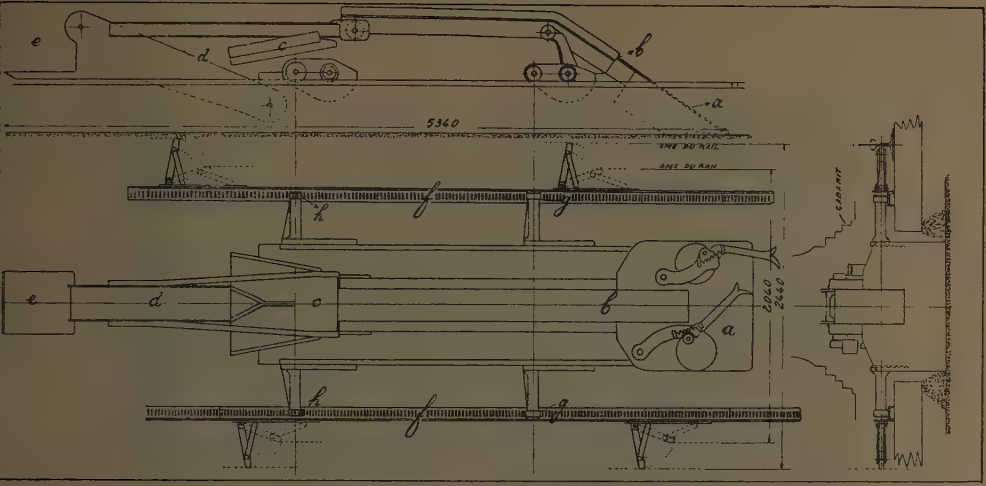


Fig. 25.

Explanation of French terms : Ame du rail = Rail web. — Gabarit = Gauge.

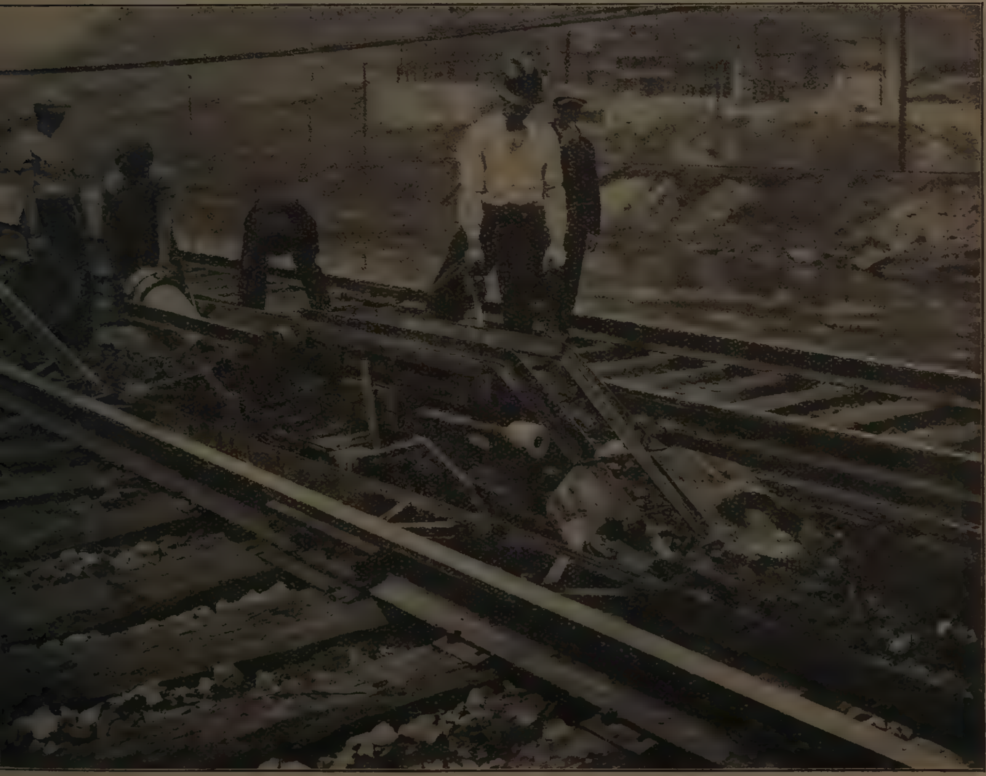


Fig 26.

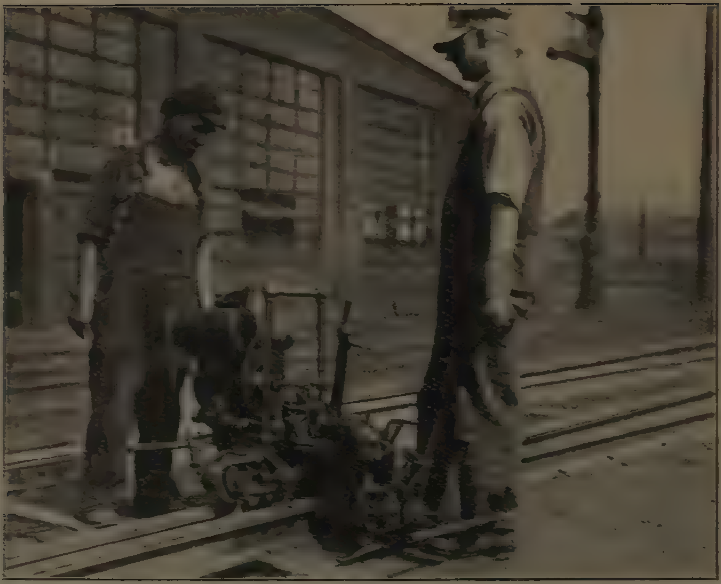


Fig. 27.

yard according to one administration; according to another they are $0.07 per foot which, assuming a bed of ballast 1.83 cubic yards (per yard) in thickness, works out to about the same. The machine can clean a length of 700 feet of double track per day; it can even be used economically when a length of 6 miles per season has to be cleaned. The plant is tended by a foreman, a driver and seven men.

One of the companies gives the cost of cleaning the ballast by means of forks as $1.67 per cubic yard and by means of hand screens $0.65.

By employing cranes, as well as with the « McWilliams Mole » there is also the advantage of cleaning in a season a greater length of track with fewer men than when this work is done by hand.

Straightening, cutting and drilling rails.

Several administrations have replied to question 1 (*o*) in the affirmative, although they only employ tools for cutting and drilling rails that are not power driven. It is obvious that this work cannot be done without tools and the question only refers to the cases where these tools are driven by a motor of some kind. Starting from this point of view, seven companies have replied that they employ mechanical appliances for drilling rails; two of these companies also make use of similar appliances for cutting rails.

The operation of drilling the rails is effected in most cases by means of drilling machines driven by petrol engines (fig. 27), which rest upon, and may be moved along, one of the rails of the track. The plant is attended to by two men; the motor is of three to four horse power. The price varies between $400 and $590. The working expenses are according to one source $0.02, according to another $0.12 to $0.25 per hole, the diameter of which is not, however, given. Hand drilling would require, according to a second source, an expenditure of $0.52.

One administration employs compressed air drills driven from the same power plant as the rammers. It is stated that mechanical drilling machines cannot be employed economically except when holes have to be drilled over considerable lengths of track, it being impossible, however, to specify this length.

For cutting rails, one company employs tools driven by a petrol engine; another uses an oxy-acetylene blowpipe, which gives a very clean cut in a short time; this method is not desirable, however, for rails in the main lines.

Other maintenance tools.

Several administrations employing the Jordan spreader (fig. 14) make use of this machine for effecting several operations. By extending the wings, it may be employed in cleaning the ditches and in keeping in order the banks and those of the cuttings and embankments. As shown in figure 28, the Jordan spreader is employed for clearing away snow from the track and the sides.

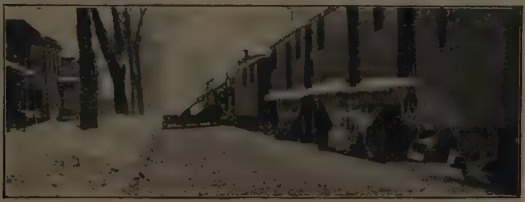


Fig. 28.

Several administrations lubricate the running side of rails in curves, so as to reduce wear. Figure 29 shows one of the machines which have been specially constructed for this purpose. The price is $700; the cost of lubricating is $3 per mile. Apart from the reduction in wear, other advantages which are pointed out are that heavier trains may be run, the tyre wear is less, and no grinding action occurs when running through a curve.

Another machine, employed on some railways for the same purpose is the « Jordan spraying machine » (fig. 30), which is also used for lubricating the rail joints and for spraying the track with oil so as to lay the dust. It is claimed that by using heated oil under pressure, the oil penetrates all the parts of the joints thus lubricating the surfaces where the fishplates bear against the rail.

Great Britain and Ireland.

According to the replies received, the use of mechanical appliances is very restricted in Great Britain and Ireland. One might say even that, compared with the data given in the report compiled by Mr. W. H. Coomber for the London Congress, the use of these appliances has

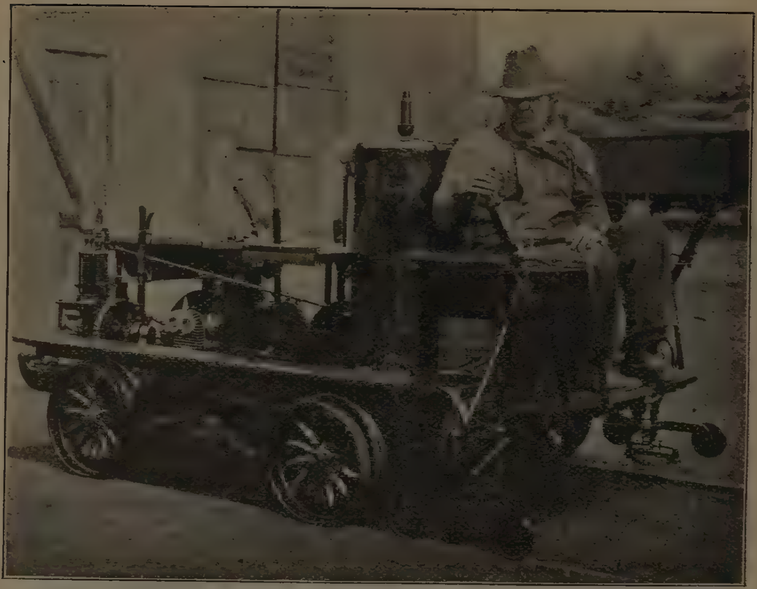


Fig.

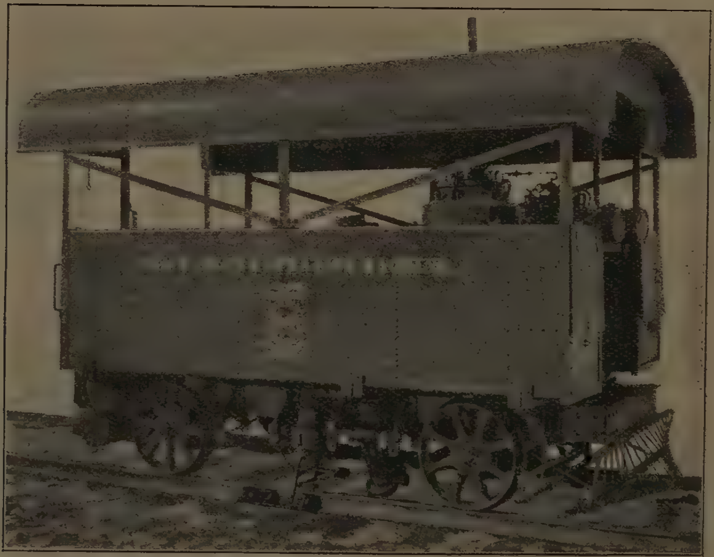


Fig. 30.

diminished, several machines quoted in the said report not being mentioned in the replies to the present questionnaire.

The different machines employed in America having been dealt with fully and nothing special having been found for Great Britain and Ireland, the cases in which mechanical appliances are employed will be merely mentioned.

A fairly large number of administrations make use of portable steam cranes for renewing points and crossings.

About half the companies make use of ballast trucks with discharging hoppers. Usually a plough fixed to a goods wagon or to a special truck is employed to spread the ballast unloaded.

One company states that they are making arrangements to employ the « Bretland » method for unloading and laying portions of the main lines, but as they do not yet give any results, the writer does not believe it necessary to enlarge on this point.

A machine for lifting and moving the rails appears to be used fairly extensively. This appliance is mentioned in the report compiled by Mr. W. H. Coomber for the London Congress; this report also gives a drawing of the machine.

The English companies all secure the rails to the sleepers by means of cast iron chairs (Mr. Coomber's report gives a sketch), and consequently the chairs are fixed on the sleepers at the creosoting sheds (one company has the sleepers delivered completely fitted by the contractor). There is no need to describe the machines for adzing and drilling the sleepers, nor those for screwing in the coach screws; no administration using a permanent way of this type would think of doing this work by hand.

One company states that petrol engines are employed for cutting and drilling rails.

By far the majority of the companies employ special wagons for carrying ballast, rails and sleepers. This stock having been described in Mr. Coomber's report, where several diagrams are also given, it has been throught sufficient merely to mention the fact of their use.

South America, India and the British Colonies, the Dutch Colonies, China and Japan.

Naturally, in countries where labour is comparatively cheap, the use of mechanical appliances is hardly general. This is shown in the replies to the questionnaire.

Several companies, however, with permanent way with wooden sleepers fitted with chairs, employ machines for adzing and drilling the sleepers, a practice which is general where the sleepers are fitted with cast iron chairs. The machines are installed at a central depot; their cost price varies between £1 000 and £1 500; they are driven either by steam or electricity, and to operate them a foreman and eight or ten men (natives) are needed. The cost of adzing and drilling a sleeper is given in one case as 3 1/2 pence, in another 1 shilling and in a third 2 millièmes (Sudan).

Hopper wagons for conveying and unloading ballast are also fairly common; six companies use them.

Two administrations, one in Argentine and the other in Africa, mention the use of compressed air tampers of the Ingersoll Rand type. One of these companies which employs eight rammers, states that they cost £1 150; no saving has been noted, although the machine is only used for distances of several miles, but this method of packing is preferred on account of the excellent results obtained. A length of 600 to 800 feet is packed without moving the compressor.

One Chinese company has made a trial of compressed air rammers; the result was not satisfactory, and the machines are no longer in use. It would be interesting to know what type of machines these were, and in what respect they failed to give satisfaction.

It still remains to be mentioned that one of the Argentine administrations employs 5-ton cranes for laying the rails, and renewing switches and crossings; compressed air drills; oxy-acetylene apparatus for cutting rails and a mowing machine worked by hand, which only cuts high weeds outside the track, without pulling them up by the roots. There is also one railway which weeds the track by means of rakes drawn by horses, and another which uses a weed killer.

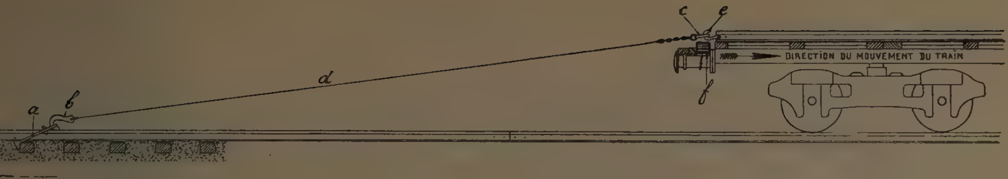
Holland.

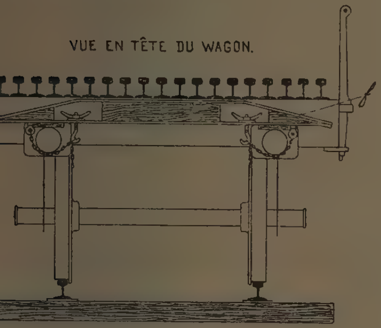
In Holland, where the railway companies are combined under one management, the railways being operated as one unit, the use of mechanical appliances has not assumed any considerable proportions.

Several years ago, the rails were unloaded, theoretically, by sliding them along skids placed against the trucks, the rails being held by ropes to prevent them from falling on to the track. In practice, however, the men lifted a rail, carried it to the edge of the truck, and released it as nearly as possible together, allowing it to fall on the ballast. The small amount of time available for unloading the rails led to this evil practice, which resulted in bent rail ends.

In order to remedy this drawback, a trial was made with a device composed of two steel cranes with a horizontal shaft which were secured to the floor of a flat-bottomed wagon. Two small trolleys, one running along each of the shafts enabled the rail, suspended by tongs attached to a chain, to be brought to the edge of the wagon and then to lower it by tackle into the ballast. Unloading was effected in a convenient manner as soon as the cranes were secured to the truck, but the removal of the cranes from one wagon to another occupied so much time that the method had to be abandoned. It would have been possible to provide each wagon to be unloaded with a pair of cranes, but the number for the entire railway system would have been too great to be sufficiently economical.

For the last two years the following method has been adopted for unloading rails (18 and 15 m. = 59 ft. 5/8 in. and 49 ft. 2 1/2 in.) long. The rails loaded on bogie flat wagons with stanchions are unloaded (fig. 31) by attaching them to a cable while the wagon moves forward. Two rails are unloaded at a time, one on the right of the wagon and one on the left. For this purpose, grapples *a* are hooked under a rail behind a sleeper, the hook *b* is inserted in the eye of the grapple, while the rings *c*, attached to the other end of the cables *d*, which are 12 m. (39 ft. 4 1/2 in.) long, are fastened to the hooks *e* fixed by means of a pin in one of the fishplate holes in the rails. On moving the train slowly forward, the two rails are pulled off the wagon. When the cables are tightened, they are drawn toward the outside of the track so that the rail ends, as soon as they touch the ground, are outside the track. The end of the rails still on the wagon is gradually guided while the train advances toward the wagon side, eventually reaching the sliding plate *f* attached to the buffers of the wagon. The sloping portions of the sliding plates cause the entire rail to fall out-





Explanation of French terms: Direction etc. = Direction of movement train. — Vue en tête du wagon = View of front end of wagon.

Fig. 31.

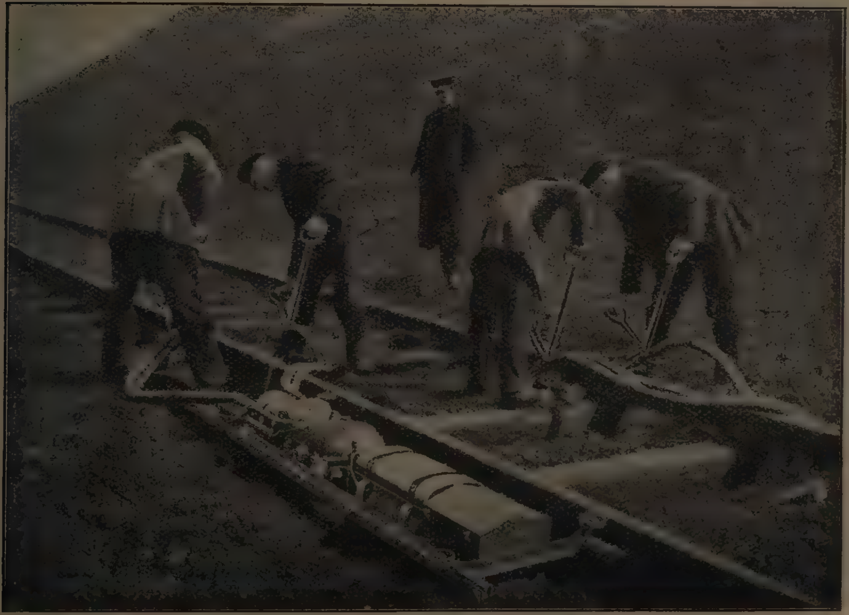


Fig. 32.

side the track. It should be understood that the rails lie with half their length on the ground when they are released from the wagon, and fall therefore very gently and without any damage. When two rails have been unloaded, the train moves back, so that the cables may be attached in such a fashion that the second pair joins the first. When the last wagon of the train has been unloaded, it is left in position and scotched and the operation is continued with the next wagon. After unloading all the wagons, the train returns to couple up the wagons left behind.

In order to unload a 40-ton wagon [approximately 4 rails of 46 kgr. (92.7 lb. per yard), 18 m. (59 ft. 5/8 in.) long] a foreman and seven or eight men are required; the time taken is about three quarters of an hour. Unloading is often carried out at night without difficulty. The method does not aim at making any savings, but is merely intended to effect the unloading of the rails without damaging them. The cost of the equipment has not been taken into account.

In order to distribute material along the line, extensive use is made in addition to trolleys, of « pony cars » (fig. 8).

The operations of drilling and adzing the sleepers are carried out at the creosoting shed when cast iron chairs and the « Est » system with poplar sole-pieces are used. In certain cases, sleepers which have to be fitted, when in the track, with sole plates, secured by coach screws, are also drilled before creosoting, so that it will not be necessary to damage the protecting layer by drilling holes.

Compressed air tamping machines have also been tried in Holland. Although the results are not altogether disappointing, they will not result in a general use of these tampers. Unlike the tampers employed in America and elsewhere, the compressed air tampers are not provided with a central power plant, but for each pair of tampers there is a small petrol engine with compressor, which, placed at the side of the rail outside the loading gauge, is readily moved as the work advances (fig. 32). The packing done by the machines is excellent, but the motors required so much attention and there were always so many under repair that the regular progress of the work was too frequently interrupted. The trial clearly showed that the motors are not robust enough. In these circumstances it has not been possible to determine the working expenses. The purchase price is 1 800 florins for a machine with two tampers.

For weeding, some lines employ a Karlsson machine, which is attached behind an ordinary flat wagon, this wagon being pulled by a locomotive. The machine consists in its essential part in two plough shares which dig up the ballast outside the sleepers, tearing up the weeds which have then to be removed by means of forks. Since the work obstructs the track, the machine can only be used on lines where the traffic is not heavy. The machine costs $3 400; the running expenses have not been ascertained. On lines where traffic is light, 15 km. (9.3 miles) of track may be cleaned in a day. In addition to weeding, the machine assists drainage by loosening the earth of the berms.

A few tests have been made with the view of destroying weeds by using chemical products. In order to make a comparison with manual labour, the cost of the latter was first determined and found to be 5.26 cents per yard of track per year to keep the track free from weeds.

If sodium chloride costing 0.35 florins

per kgr. (0.159 fl. per lb.) is used, a 2 % solution is necessary. 4 000 m² (4 784 sq. yards), *i.e.* a length of track of about 1 000 m. (0.621 mile) is sprayed with 10 m³ (2 200 British gallons) of solution. The total cost is therefore 200×0.35 fl.= 70 fl.+30 fl. for the labour, or 0.10 fl. per metre (0.0915 fl. per yard) of track. The weeds wither up almost completely, but after a month a few shoots of grass are to be seen growing again. It is very probable that the same treatment will have to be repeated in the same season.

A second test has been made with a product called « Paraplant » which also costs 0.35 fl. per kgr. and which is used in a 5 % solution. The liquid is distributed by means of an atomiser: with 10 m³ (2 200 British gallons) of solution, 25 000 m² (29 900 sq. yards) are treated, *i. e.* a length of 6 250 m. (3.88 miles). The cost is 500×0.35 fl.=175 fl.+185 fl. for the labour, which makes 0.058 fl. per metre (0.053 fl. per yard) of track. The weeds appear to die, but that does not prevent a few blades of grass from appearing within six weeks after the treatment. It is probable that during the first season of application, the treatment will have to be repeated.

These preliminary tests have led to further tests with Paraplant. It is not certain whether any saving will be effected but even if they were not very appreciable, it would be an advantage to be able to clean a certain length of track in less time, and therefore with fewer men, who could be employed on other work in connection with the upkeep of the permanent way.

CONCLUSIONS.

1. It is in the United States of America and in Canada that the use of mechanical appliances has become very extensive. Such appliances are almost universally employed for loading, transporting and unloading ballast, for unloading rails, laying rails, and packing and cleaning the ballast.

2. In Great Britain and Ireland, the use of mechanical appliances has not made much progress. Comparing the information received for the present report with the report for the London Congress in 1925, we believe there has been a slight set-back to be noted in the use of these appliances. The loading, transport and unloading of ballast only is generally done by means of special self discharging wagons.

3. In South America, the British Colonies, China and Japan, mechanical appliances are rarely employed, which is due to the relatively cheap labour.

4. In Holland, special appliances are only used for unloading rails.

5. The saving is very appreciable in certain special cases as regards unloading ballast, rail-laying, and the packing and cleaning of ballast. In almost all cases, there is the advantage that the work is done better, which results in a permanent way that is more suitable for heavy and fast traffic.

6. We believe that the extent to which mechanical appliances are used in the United States of America and in Canada is to be attributed not only to the high wages, but also to the mentality of the American workmen.

CHAPTER II.

Rational organisation of the maintenance of the permanent way.

The first question : « What is the organisation of the maintenance of the permanent way on your system? » has induced a large number of the administrations to give a more or less extensive review of the entire management, beginning with the general management and ending with the platelayer. This subject was fully dealt with in the reports compiled for the Rome Congress in 1922. Reference may be made, therefore, to these reports.

United States of America and Canada.

Organisation of maintenance and inspection.

It follows from the replies received that in all the administrations the employees are uniformly distributed over the lines, in this sense, that the density of traffic, the presence of large stations, portions of the permanent way which require more upkeep, etc., are taken into account, so that the number of men in the gangs is greater for more important lines or portions of lines.

There are very few companies who have not a special staff for the upkeep of works, tunnels, bridges, etc.

On many of the railways, special watchmen are employed for the bridges, tunnels, or even, in certain cases, for the long and deep cuttings.

As a rule, level crossings are not guarded; all the crossings are provided, however, with a special signal informing vehicles that they are approaching a railway. When the traffic is dense, or when the view of the railway is obscured from the road, special precautions are taken consisting in the use of steady lights or automatic flashing lights, or in providing a guard for the level crossing. Both precautions may also be taken. One administration states that these measures are only employed during a certain part of the day, a practice which is in little use and in the opinion of the writer not very commendable.

The general practice is that the lines are inspected once a day by a man from the gang called the « track walker », who works with his gang for the remainder of the day. Only one administration has given a negative reply, while another states that this inspection is only done regularly on the main lines; on secondary lines it is only done when it is required.

As far as replies have been given to the question, it must be admitted that in general the watchmen are relieved by the platelayers.

Most of the administrations have not introduced in recent years into the organisation any innovations intended to effect a more economical maintenance of the permanent way: one company says that the matter is being investigated. Three administrations have replied in the affirmative to question 2; one says that they have increased the distance covered by the gangs by introducing the use of rail motor vehicles for the transport of men and material. The second mentions that a prize is given to the foreman whose tracks are kept in the best condition with the fewest men; the third has a special organisation consisting of a maintenance engineer with several inspectors, who make special investigations with the view of fixing standard methods of maintenance to increase the productive force and economise in the use of material.

Permanent way equipment.

The rail generally employed for the main lines is one of 130 lb. per yard, and 39 feet long; one administration mentions even the use of a rail of 136 lb. per yard. For secondary lines the weight of the rail is 100 lb. per yard. These weights are much heavier than those used in European practice, and it should be noted that the reasons which have led to the use of such heavy rails are : 1. The hope that the heavy rail would reduce the maintenance costs of the track; 2. A longer life for the rail; 3. Less fractures; 4. A better track as a whole.

The fishplates, the fishing angle of which varies between 14° and 18°, corresponding to a slope of 1 : 4 and 1 : 3, are generally secured by four 1 1/18-inch bolts. In some cases six bolts are used. The joint is almost always found to be suspended; one case is mentioned where the fishplate rests on three sleepers, that is to say, one of them is under the joint, thus forming a supported joint, the other two being at a distance of 16 3/8 inches from centre to centre, which must cause difficulties with respect to packing.

The 39-foot rail is laid on 24 sleepers; the sleepers used by most of the administrations are hard wood. The writer considers this to be an excellent practice; although the sleepers of hard wood cost more than pine sleepers, the former, owing to their longer life, are much more economical. The short distance between the sleepers [50 cm. (1 ft. 7 11/16 in.) from centre to centre] is, in the writer's opinion, a measure which reduces the maintenance cost of the track.

Practically all the administrations fit the sleepers, even when of hard wood, with sole plates, which are often in the form of a wedge, giving the rail an inclination. Most frequently, this is usually found to be 1 : 20, but 1 : 44 is also used. The rails and the sole plates are always secured to the sleepers by spikes.

With a few rare exceptions, the ballast is of broken stone. Efforts are also made to strengthen the track and to reduce the upkeep expenses by increasing the thickness of the bed of ballast which is often 50 cm. (1 ft. 7 11/16 in.) underneath the sleeper; a figure of 60 cm. (1 ft. 11 5/8 in.) has even been noted.

Strength of the permanent way maintenance gangs.

The replies to this question do not enable a general idea to be given of the length of track kept in repair by a gang or of the number of platelayers. There are some railways which take the length of the line as a basis, without indicating the number of tracks, others refer to the length of the main lines, while there are yet others which give the equivalent length of single track, the only rational basis in the opinion of the writer.

It can be stated, however, that the length of track kept in repair by a gang varies between 5 to 12 miles of main line, the number of men in a gang in Summer being 5 to 11 men. It would be a mistake to conclude from these figures that the number of men in a gang is in general 1 per mile because the replies give such divergent figures that such a conclusion cannot be made. Moreover, if reference be made to the report by Mr. Randolph for the Rome Congress, in which he recommends a staff of one man per mile, and also to what Mr. Stimson says in his supplementary report to the same Congress, where it is stated that the regular gang varies between the equivalent of one to two men per 2 miles in winter and of one to three men per mile in the season of the greatest activity, the only conclusion which remains to be drawn is that average figures have no value whatever, the circumstances for the different railways being so variable that each case should be considered apart.

Of the 13 administrations who have replied to the questionnaire only 3 do not employ formulae for determining the number of workmen necessary for the maintenance of a certain length of track. This shows at once the great value which is to be attributed to these formulæ. In the writer's opinion they form the only rational base; no serious objection can be raised against their use, provided emphasis is placed on the word « base », so that all cases in which it is necessary to depart from this base shall be well studied and considered.

Several administrations employ formulæ which are so simple and so easy to apply, that their use, if there is no desire to go deeper into the matter in order to arrive at more exact data, is quite straightforward. These formulæ simply give for the different elements of the track, an equivalent length of main line track. One railway reckons for one mile of main track :

1.15 miles of second main line track,
1.33 — of third and fourth main line tracks,
2.00 — of branch line track,
2.00 — of passing loop track,
3.33 — of holding sidings track,
12 turnouts in main line,
20 — in sidings.

After establishing on this base the number of men (it is not stated how many are alloted per mile) the railway crossings, level crossings, ditches, fencing, interlocking plant, water towers, etc., are taken into account, the final result being an individual investigation for each gang.

Another example of the same kind is the following, where for a mile of main track are reckoned :

1.00 mile of second main line track,
2.00 miles of running track,
2.00 — of heavy switch lead,
3.00 — of loop track,
4.00 — of holding siding track,
6.00 — works sidings,
20 turnouts in main line track,
40 — in sidings track,
20 crossings,
5 double cross-overs,
10 special lap switches.

This administration allots 1 man per mile of main track.

Certain administrations have gone deeply into the matter in order to determine the amount of work required for the maintenance of each part of the railway, and in this way have arrived at a differentiation, enabling the number of men in a gang to be fixed on a basis almost entirely resulting from the formula. That mentioned by the Canadian National Railway is reproduced here. This formula gives for each object a factor which must be divided by the length or the real quantity, in order to obtain the equivalent length in miles. These divisions are different for the different sorts of railway (depending upon the intensity of traffic) of which there are five classes :

OBJECT.	Unit.	Classification of lines.				
		Class A.	Class B.	Class C.	Class D.	Class E.
Single line	Mile.	1.0	1.2	1.4	1.7	2.2
Double line	"	0.6	0.7	0.8	1.0	...
Triple line	"	0.4	0 5	0.6	...	...

OBJECT.	Unit.	Classification of lines.				
		Class A.	Class B.	Class C.	Class D.	Class E.
Quadruple line	Mile.	0.3	0.4	...	...	...
Loops	»	2.0	2.4	2.8	3.4	4.2
Sidings	»	2.8	3.3	3.9	4.6	5.6
Works and shed lines	»	3.5	4.2	4.9	6.0	7.0
Tunnel lines	»	0.8	1.0	1.1	1.3	1.7
Turnouts on main line	Number.	12	14	16	19	22
Turnouts on sidings	»	15	17	20	24	28
Cross-overs	»	6	7	8	10	12
Main line crossings	»	10	12	14	17	20
Siding crossings	»	14	17	20	24	28
Communal level crossings with heavy traffic	»	10	12	14	17	20
Communal level crossings with average traffic.	»	14	16	19	22	26
Secondary road level crossings with average to light traffic.	»	18	21	24	28	34
Main road level crossings with heavy to average traffic.	»	25	30	35	42	50
Main road level crossings with average to light traffic.	»	37	44	52	61	70
Level crossings with country roads	»	50	60	70	85	100
Level crossings with unimportant country roads.	»	60	72	84	100	120
Ditches (other than the ditches of cuttings)	Mile.	5	5	5	5	5
Fencing	»	20	20	20	20	20
Interlocking plant	Number.	3	4	5	6	6
Automatic signals	»	20	24	28	33	40
Yack catches	»	50	60	70	85	100
Station sites	»	6	7	8	12	18
Water towers	»	5	6	7	11	15
Coaling stations	»	4	5	6	7	8
Ash roads	»	3	4	5	6	6
Open and closed goods sheds	»	17	17	17	17	17

The application of this formula to a section of line of class A gives :

OBJECT.	Actual quantity.	Factor.	Equivalent miles.
Double line	3.0	0.6	5.00
Loop lines	1.1	2.0	0.55
Sidings	1.5	2.8	0.54
Shed lines	0.7	3.5	0.20
Turnouts (main line)	6	12	0.50
Turnouts (sidings)	6	15	0.40
Railway crossings (main line)	1	10	0.10
Secondary road level crossings (average traffic)	1	14	0.07
Secondary road level crossings (light traffic)	2	18	0.11
Mains road level crossings (average traffic)	2	37	0.05
Level crossings of little importance	10	60	0.17
Ditches	1.6	5	0.32
Fencing	6.0	20	0.30
Interlocking plant	1	3	0.33
Signals	4	20	0.20
Jack catches	2	50	0.04
Station sites	1	6	0.17
Total			9.05

For a gang which, including the foreman, consists in summer of 6 men and in winter of 4 men, this will be equivalent therefore to 1.51 miles per man in summer and to 2.26 miles per man in winter.

The administration thus compares each effective with the formula, and makes sure that the strength of the gangs agrees with the formula; if it does not, enquiry is made into the cause for the discrepancy in order to ascertain whether there are justifiable reasons for it.

All the administrations without exception state that the number of men in the gangs is greater in summer than in winter. A distinction should be drawn between the ordinary work of keeping the track in repair and special work, such as renewing rails, sleepers and ballast. It is obvious that, when a gang has much special work to do, the gang must be specially reinforced, or such work entrusted to a special gang. Both methods are in use; in the writer's opinion, that of reinforcing the gangs is preferable, the work of renewing the track then being done by the men who will be required to carry out the ordinary maintenance work.

Moreover, most of the administrations adopt for the ordinary work also a different effective for the gangs in winter than in summer. It is even possible to find figures which are used as basis, these being, for one administration in winter

0.5 man, in summer 0.8 man per equivalent mile; for another, in winter 1 man, in summer 1 1/4 man per equivalent mile.

Some administrations employ the formulæ for calculating the strength of the gangs required in winter. It does not seem justifiable to the writer to calculate the strength of a gang at a season when most of the maintenance work is suspended. In his opinion, the formulæ should give the basis for the effective of the gangs during the season when the chief work, that is to say, the upkeep of the lines, is done. In the winter the number will be reduced as much as possible, only the work which is absolutely necessary being taken into account, such as small repairs to the track, removal of snow and ice, relief of watchmen, etc. This method does not, of course, mean that the workmen employed in the summer will all be employees of the railway; it is rational to consider as railway employees only the workmen employed all the year round, the gangs being made up in summer by temporary workmen to the requisite force.

The cleaning of ditches, the upkeep of hedges, etc., are performed, according to the replies received, always by the gangs. Although only a few railways make any definite statement to this effect, it may be assumed, except in a few rare cases, that the work of maintaining and renewing the permanent way is done by the railways' own employees, and is never confided to contractors, in the writer's opinion, a very sound way of working.

Method of maintaining the permanent way.

The maintenance of the permanent way by the method of a periodical general renewal, is unknown in America. One administration states that they renew each heavy traffic line every four years. It is obvious, however, that this does not constitute a general overhaul, which, judging by the replies received, does not appear to have been adopted generally. It may be recalled, that in subjecting a section of line to a general overhaul, each component of the track is examined and, if necessary, renewed at the same time. Attention is paid, therefore, not only to the rails, the sleepers and the ballast, but also to the joints, sole plates, the gauge and cant of the track, etc., so that, once the general overhaul is over, all the components of the section of line are in perfect condition. It is evident that, for a railway track maintained in this manner, not only will the traffic run smoother, since there will no longer be anything to prevent this, but the wear will be less because all the parts of the track will have been renewed and the play between them will be as small as possible. The writer considers the general overhaul to be an eminently economical and rational method of permanent way maintenance.

In replying to question 10, several administrations refer to information provided for the first part of the present report. As regards the preparation of material before it is placed in the track, it is the universal custom to creosote the sleepers, while two administrations also mention the use of steel containing 1/4 % copper for the sole plates and the spikes. The average life of the rails varies from 6.4 to 10 years in the main-line tracks; one reply, indicating a life of 6.4 years, adds that the life in curves is from 4 to 6 years, and in straight portions, 10 to 12 years, while after having done service in the main-line tracks, the rails are laid in tracks of lesser importance, so that their total life until they are reduced to the state of scrap, is 32 years. The use of steel containing 1/4 % copper is too recent to enable any opinion to be advanced regarding its life.

The life of the creosoted sleepers varies very much judging by the replies received. One administration, basing its figures on a 15 years' practice, estimates their life to be 20 to 25 years. Another gives 25 to 30 years as an estimation, and others indicate 20 years and 16 to 20, while finally, according to one of the replies, creosoting increases the life of the sleepers by 6 to 8 or 10 years. Although it is a common opinion that creosoting increases the life of sleepers to such an extent that the process is economical, the figures here given do not enable this conclusion to be drawn in general, the figures showing moreover that the renewal of the sleepers is not only due to rotting but also to mechanical wear as a result of the traffic conditions.

As regards the care bestowed on the material while in service some administrations mention the use of a lubricating oil for the fish-joints and the moving parts of switches, and another cutting off the rail ends in order to renew the fish-joint.

When laying lines on curves, the method of measuring the height of the arc is employed.

None of the administrations replying to the questionnaire has work done by contract by its own employees, nor gives bonuses for completing certain work within a certain time. The writer considers that what is formulated in one of the replies states very clearly the reasons for not using these methods :

« Our employees are paid by the hour;
» they are required to work as hard as
» they can while on duty. If they were
» given bonuses for doing their work
» properly, it would mean after all that
» they would receive double pay for doing
» their duty, which would not only be
» contrary to an economical way of work-
» ing, but would cause discontent among
» equally capable men who might not be
» rewarded in the same manner. »

The argument is without doubt *theoretically* sound, but in order to be able to apply it, it is necessary to be certain that each man does work as hard as he can.

Six administrations have given the annual maintenance costs per mile of single main-line track. The length of these six railways is :

In miles:

211 1 378 1 570 2 524 5 150 10 520

The annual maintenance costs :

in dollars per mile:

3 200 1 330 2 200 2 500 2 200 2 950

Since it is not stated whether these figures, which are moreover very divergent, represent the maintenance costs for the whole of the equipment of the railway or only those of the lines and buildings (one administration even gives two figures, one of which shows all the costs including depreciation for everything which is connected to the permanent way), little value can be placed on any comparison.

The special measures taken by the railways to increase the life of the material where traffic is heavy (question 16) differ greatly. We find the following : use of heavy rails, hard wood for the sleepers, heavy sole plates, ballast of broken stone, increase in the number of sleepers, creosoting of sleepers, and lubricating the fish-joints. One measure which several administrations state as being effective is to lubricate the running side of rails on curves, which considerably reduces wear.

Conditions of service.

The hours of work are not fixed by law, but by agreement with the employees' unions. The working day is usually 8 hours for platelayers; for watchmen it is 10 hours on some railways. In urgent cases, the normal hours are extended without limit, although one administration gives 16 hours as the absolute maximum. According to the replies received, it is a very general custom to pay for overtime between 8 hours and 10 hours the same rate as the ordnary time, while for hours after 10 an increase of 50 % is paid. In some cases this increase is paid even for overtime above the ordinary 8-hour day.

Without exception, the administrations reckon the time from the moment the workman reaches a certain point, which is frequently the shed of his gang, but which may also be a station or any other place where work has to be done. Work is never reckoned to begin the moment the workman arrives on the railway precincts at the nearest point to his domicile.

Very frequently, the gangs are provided with rail motor vehicles to convey the men to their place of work. These vehicles always travel under the responsibility of the conductor, who very often is the gang foreman, or a man acting for him, and who finds out from the foreman the movements of the trains. In one of the replies it is stated that the foreman has to give a written order, and in two others that the rail motor vehicles are regarded as trains either because of the heavy traffic or because the line is single.

From the replies received it appears that the men of the Signal Department and the Telegraph Department are always provided with motor rail cars; the workmen use them in many cases, either a car specially provided for them or the car of the gang. The use of bicycles is rarely mentioned. The machines are in all cases the property of the Administration.

Only one administration has replied in the affirmative to the question concerning the use of graphs showing the progress of work, but no information is given. The other administrations do not use graphs. There is one, however, that has ascertained by means of a special investigation of the different operations, in what manner and in what time these operations may be made. These details are applied to each different piece of work, taking into account the varying factors, such as intensity of traffic and the resulting loss of time. Each division receives every week a return showing the quantity of material used, and the time spent on each piece of work. In this way some idea is obtained of the progress of the work and the time required for putting in place each item of material. Once a month the divisions send a return to the central administration, from which the data for the entire railway are extracted, enabling a comparison to be made between the divisions. Another railway appears to act in much the same fashion.

As to the information concerning the different operations referred to in question 17, one reply mentions the quantities dealt with daily without giving the number of men and of the machines employed, while another gives the price of each operation. The prices are as follow :

	Dollars.
Unloading 1 ton of rails and loading the rails removed from the track	1.12
Unloading 1 ton of ballast . .	0.19
Renewing 1 metre (1.09 yard) of rail	0.21
Packing 1 sleeper in clinker ballast	0.10

Packing 1 sleeper in broken stone ballast	0.08
Lining up 1 metre of track in clinker ballast	0.10
Lining up 1 metre of track in broken stone	0.22
Renewing 1 sleeper	0.75
Cleaning 1 m³ (1.3 cubic yard) of ballast	0.56
Weeding 1 metre of track	0.33

Appointment and professional instruction of the employees.

All the railways select their foremen from among the men of the gangs, taking into account their capability and their seniority. Very often a medical certificate is required, while one railway makes them pass an examination on the « Book of rules », which contains all the rules governing the employees and their work; every year it is made sure that the employees are still well acquainted with these rules.

It is very rare that the inspectors are taken from outside the ranks of the gangs, although a professional certificate is generally required for these employees. One railway, possesses among its staff employees having the rank of inspector of tie renewals, who are selected from among the foremen, the higher supervision being made by civil engineers; the latter begin their career as Assistant supervisor of track, which gives them the opportunity of becoming absolutely familiar with all the work, and opens for them the ranks of Supervisor of track and afterwards « Division engineer, maintenance of way ».

None of the administrations who have replied, facilitates the training of its staff by means of schools or courses of instruction (one states that this subject is being investigated). Several railways, however, encourage their employees to study, either by encouraging them to read books and periodicals (which in many cases are placed at the disposal of the readers by the Y.M.C.A.) or to become members of an organisation which holds lectures every month in the evening; they are able to attend these lecture owing to the organisation of special trains.

Great Britain and Ireland.

Organisation of the maintenance and inspection.

All the administrations whose replies have been received possess a staff of workmen entrusted with the maintenance of the permanent way, and who are distributed over the lines in the same manner as was mentioned in connection with the United States of America and Canada. One company has in addition special mobile gangs of 24 men who attend to special jobs.

There are very few railways who have special gangs for the maintenance of works, such as tunnels, bridges, etc., while about half have special watchmen for these works or for deep cuttings.

Level crossings with public roads are generally provided with barriers and are guarded. The regular inspection of the permanent way is carried out on principle once a day by the gangers.

With regard to the question relating to the introduction, within the last years, of innovations aiming at a better and more economical maintenance of the track, only two systems replied in the affirmative; the one uses rail cars so as to make easier the movements of the staff; the other concentrates the gangs, which doubtless aims at closer supervision.

Permanent way equipment.

With the exception of one company having a very small total length of line, and using rails of 60 lb. per yard spiked directly to the sleepers, without plates or shoes, all the companies have a permanent way with rails of 95 and 85 lb. per yard, 45 and 60 feet long attached to 18 or 24 sleepers by means of cast iron chairs weighing 46 and 40 lb. Drawings showing the details of this track are to be found in the report by Mr. Coomber, for the London Congress. Some companies employ wider sleepers under the joints, which appears an excellent practice to the writer. The sleepers are always of red wood and creosoted. The English practice of making sleepers having a section of 5×10 inches from 10×10 inches timbers by sawing them length wise in the creosoting shop is well known. The ballast is almost always of broken stone; some companies also use for ballast hard clinker.

Strength of gangs for the maintenance of the permanent way.

On the railways of Great Britain and Ireland, the length of line kept in repair by an ordinary gang is 5 miles and the number of platelayers in a gang is 4 or 5, including the foreman. The figures are very different for the railways of London and its environment, but the factors there are so very different that it is unnecessary to take these cases into account.

Some administrations have stated the basis on which they fix the effective of the gangs. In one case we find 1 man for 1 to 1/4 miles, depending upon the importance of the line; in another 0.9 man per equivalent mile, and finally in a third, 0.9, 0.7 and 0.5 man per equivalent mile for lines of the first, second and third classes.

Most of the railways do not make use of formulæ, for determining the number of workmen required for the maintenance of a certain length of track. The number is fixed according to practice, taking into account the special features of each section. A few companies only employ very simple formulæ, merely taking into account the length of loops and sidings (very generally on the basis of 1 mile of main track = 3 miles of sidings or loops), and allotting a certain length of main track for the points [we find 1 complete set of points = 92 yards; 1 cross-over = 97 yards; in another case 1 complete set of points = 25 yards (more than the real length)].

According to all the replies received, the number of workmen is the same both winter and summer. Two companies state that renewing the track is done by special gangs.

All the companies who have replied to the questionnaire, arrange for the cleaning of ditches, the repair of hedges, etc., to be done by the gangs; only one railway states that they have special gangs for the repairs to fencing and barriers. Contractors are never resorted to for the work of maintaining the permanent way and its details.

Method of maintaining the permanent way.

In Great Britain and Ireland, the method of general periodical renewal is unknown, the repairs and renewals being made when the need makes itself felt. Many companies have special gangs, not for the general overhaul, but for renewing the track.

As regards the preparation of the material before it is placed in the track, it is quite general to creosote the sleepers while many companies mention the use of galvanised coach screws.

The information received concerning the life of the material shows a considerable divergence. One source gives, for rails, 4 to 8 years for heavy traffic, and 18 years for ordinary traffic, another indicates 6 1/2 to 20 years, etc. The life of creosoted pine sleepers varies between 18 and 25 years! One company has used sleepers of jarrah wood which have lasted 30 years. The beech or oak keys have a life of 3 to 4 years, while that of the cast iron chairs is 18 to 20 years in two replies, and 35 years in a third.

The curves are usually laid in by the method of measuring the height of the arc.

No railway has work done on contract by its own employees nor grants bonuses.

Four companies reply to the question concerning the maintenance costs : 1. — £231.87 per mile of single line including lateral lines; 2. — £2 450 per mile for renewals and £190 per mile for repairs, figures which lead one to believe that they do not refer to the annual cost per mile but to the expenditure necessary for renewing or for repairing a mile; 3. — £700 per mile of single line including renewals, and 4. — £1 000 per mile of line including the contact rail.

A special measure and one which is fairly general to prolong the life of material in the case of heavy traffic, is that of employing special steel for the rails and points, etc., especially at places (junctions) where the movement of trains is particularly frequent. In some cases the running side of the rails is lubricated.

Conditions of service.

The working hours are not limited by statute but are fixed by a National Agreement without exception at 48 hours a week, overtime being paid on a higher rate. One company says that every hour over 48 is reckoned as 1 1/4 except the hours between 10 at night and 4 in the morning, which are counted as 1 1/2.

Although some companies count the time from the moment the workman arrives at the shed, most of them count the time from the arrival at a certain place, which is very often the place where work was left off the night before, and where the tools were left. The hours of work are never counted from the moment the workman arrives on the railway property at the nearest point to his house.

Among the 10 companies who have replied to the questionnaire only one makes use of rail motor vehicles, and even then before they are allowed to run, arrangements must be made with the signalmen after which a key is taken out of an electrical instrument so as to block the signals and interrupt the passage of trains, which is certainly not in favour of a frequent use of these vehicles. Neither artisans, nor the men working on the signals and telegraphs are provided with rail motor vehicles; one case is mentioned where the latter often use their own bicycles or where they receive a special allowance.

Only one company makes use of graphs showing the progress of work, but all the details are not given, the use merely being restricted to calculating the time taken to renew 1 metre of line; other information is not given.

Appointment and professional instruction of employees.

Generally the foremen are selected from among the platelayers, taking into account their ability and their seniority. Some railways even resort to the foremen when an inspector's position has to be filled

These employees are never required to possess professional or official qualification, but the candidates have to pass a medical examination.

Two companies have organised courses for the candidates; one says that these courses consist of a series of 6 lessons which are given in different places, distributed over the railway system, by semi-official instructors.

South America, India and the British Colonies, Dutch Colonies, China and Japan.

Organisation of the maintenance and inspection.

One may say that, taking into account the density of the traffic, the existence of large stations, of portions of the permanent way requiring more upkeep, etc., the staff is generally uniformly distributed over the lines. There are some administrations, however, who allot very long districts to each gang, concentrating the men in a station which is conveniently situated. One company has instituted this principle only on sections where trains are infrequent.

Some administrations have a special staff for maintenance of works, tunnels, bridges, etc. One company has the ordinary work (cleaning, painting, etc.) done by the gangs and only the more important work is done by special workmen.

In about half the cases we find watchmen for tunnels, bridges, etc. There are some railways who only have certain points watched during the rainy season.

The most general practice is to guard the heavy traffic level crossings. Three administrations state that all the level crossings are guarded; one of them, however, makes a reduction for paths and field crossings. On the other hand, there is one company that does not guard the level crossings.

The regular inspection of the track is done by the platelayers; some railways, however, entrust this work during the wet season to special watchmen who also carry out an inspection during the night.

Five administrations have provided information regarding the innovations intended to make the permanent way maintenance more economical. The first has increased the number of gangs by reducing proportionally their effective; the second has increased the length of the divisions and sub-divisions with the view of reducing the general expenses; the third has introduced on lines of light traffic mobile gangs provided with rail motor vehicles; the fourth has taken similar steps by increasing the length to be kept in repair by the gangs on lines where the traffic is light, and finally the fifth has merely reduced the number of men in each gang.

Permanent way equipment.

The rail most frequently employed is one of 80 or 90 lb. per yard; in a few rare cases, the weight is 100 lb. per yard or 70 or 75 lb. per yard, while on some narrow gauge railways, the weight is 60 lb. per yard. The length of the rail is generally between 36 and 42 feet.

The use of fish-plates secured by four bolts is general, except in South America, where 6 bolts are used.

Reducing the information to the same base, we find for all the administrations an average distance between the sleepers varying between 2 feet 4 1/2 inches and 2 feet 6 inches, which is therefore very uniform. One company however, lays 2 446 sleepers per mile, giving an average distance of 2 ft. 2 in. per sleeper. It is a fairly general practice to lay an extra sleeper per rail length on small radius curves.

Most of the administrations employ wooden sleepers, although several employ steel sleepers (one mentions the use of reinforced concrete and that these two types of sleeper are both used on the same railway). The wooden sleepers are generally of hard wood of local growth. In the Dutch East Indies, the use of creosoted pine sleepers has not given good results.

It is not usual to protect the sleepers with sole-plates while the use of cast iron chairs is only mentioned in one case.

Broken stone ballast is in very general use. There are some railways, however, using gravel (even in association with steel sleepers), while in very rare cases earth is used for ballast.

Strength of gangs for permanent way maintenance.

Even when the 24 railways who have replied to the questionnaire are grouped geographically, a considerable variation is found in the average length of track kept in repair by a gang, and in the number of platelayers in a gang. The lengths mentioned vary between 3 and 25 km.; the number of men between 4 and 16. The variation in the strength of the gangs is very striking when, for the railways providing these figures, a comparison is made between the bases which have been used for calculating the number of men per gang. We find in the nine cases mentioned that one man is accorded for 0.53 km., 0.64 km., 0.80 km., 1.00 km., 1.14 km., 1.20 km., 2.33 km., and 4.50 km. (0.33 — 0.4 — 0.5 — 0.62 — 0.71 — 0.745 — 1.45 and 2.8 miles).

It cannot be said that a large part of the administrations use formulæ to determine the number of workmen in a gang; although 16 replies are affirmative, the « formulæ » are in most cases so simple that they can scarcely be called such. Many of the administrations merely take into account the length of secondary track by reckoning them to be 1/2 or 1/3 of their length. Other railways merely differentiate between single track and double track lines by allowing for the former, for example, 2 men per mile and for the second 3 men per mile, including points, etc. Some administrations, however, allow for these fittings, for example, by allowing 1 man for 10 turnouts, and calling 40 points or crossings equal to one mile of main track; another assumes one mile of main track to be equal to 15 points or crossings.

Only three companies have more detailed formulæ. That of one of these companies is as follows:

	Class I.	Class II.
Main lines . . .	1.—	0.75
Branch lines . .	0.40	0.25
Level crossings .	0.10	
Fences	0.05	
Hedges	0.20	
Tunnels	3.00	
15 points or crossings	1.00	0.75
30 culverts . . .	1.00	

As regards the main lines, the lines are divided into two classes, while for the branch lines and the track appliances, class I comprises those where a shunting locomotive is run, and class II those without such a locomotive.

The second administration has the following equivalents :

Single main line	1
For each main line track in addition	1
Turnouts	2/3
Sidings	1/3

Works tracks	1/4
Ballast siding	1/5
Single line switches	1/20

In winter, 0.88 man is allowed per kilometre (1.41 man per mile) and in summer 0.65 man (1.04 man per mile), in addition to taking into account the number of trains, the variation in temperature and secondary occupations.

The third administration (Government General of Chosen, Railway Bureau) takes into account a large number of factors by drawing up the following rules:

A. The length of the section is converted into an equivalent length according to B. This length is increased according to the conditions set out in C, D and E in order to obtain a total length. This length is multiplied by the standard number of men per mile.

B. In order to convert the real length, the following rules are followed :

1. On double track lines, the second track is counted for 2/3 of its real length;

2. Branch lines are counted for 1/2, 1/3 or 1/5 according to their importance;

3. One set of points is counted as 1/15, 1/20, 1/40, or 1/50 according to the importance of the points in question;

4. A lever of an interlocking-frame is counted as 1/50 mile;

5. The length of curves is increased per degree of the angle at the centre :

For a radius of 19 chains or less, 1/600 mile.

For a radius of 30 chains, 1/800 mile.

For a radius of more than 30 chains, 1/1 600 mile;

6. For gradients, for each foot is counted:

1/1 600 mile for gradients of 1 : 200 to 1 : 100.

1/800 mile for gradients of 1 : 100 to 1 : 50.

1/600 mile for gradients exceeding 1 : 50;

7. For tunnels the length is increased by 30 % to 50 % depending upon their length;

8. For each temporary bridge, the real length of track is multiplied by 20/100;

9. The rail section is allowed for in the following manner :

For rails of 60 lb. per yard, an increase of 10 %.

For rails of 65 lb. per yard, an increase of 5 %.

For rails of 75 lb. per yard, no increase.

For rails of 100 lb. per yard, a reduction of 15 %;

10. When the track is lifted by frost, the real length is increased by 35 % for a lift of 3 inches or less; for a lift greater than this, the percentage is increased by 5 for every 2 inches;

11. Each mile of ditch in the cuttings is counted as 1/30 mile of main line track.

C. The number of miles calculated according to B is multiplied by 35/15 000 to 154/15 000 (the factor depending upon the weight and the speed of the trains) for every train exceeding 10.

D. The result obtained by the calculations relating to B 2, 3 and 4 is increased by a factor of up to 30 %, depending upon the number of vehicles running on the branch line.

E. The result of B is increased by up to 30 %, depending upon the temperature differences and the number of workable days.

F. The standard number of men is 1.36 per mile, with a minimum of 6 per gang.

Only one administration (in China) has laid down expressly a different effective in winter and summer. In India and Australia, the number is constant all the year round, owing to the regular climate. In Africa, the number of workmen is often increased during the rainy season, while in South America some of the men leave the railway during the harvest season, the gangs being reinforced during the remainder in order to make up for the lost time.

From the replies received, it follows that all work done on the permanent way is always done by gangs who in the majority of cases, are also responsible for the upkeep of the ditches, hedges, fences, barriers, etc. Some companies have a special gang for attending to the fences and barriers, while others entrust big jobs of this nature to contractors.

Method of maintaining the permanent way.

None of the companies employs the method of periodical general overhaul inspections, this system, to judge from the manner in which some of the replies are worded, being unknown to many companies. One company states, however, that they have not adopted this system because the system of maintenance as found necessary is much more economical.

The preparation of material before it is placed in the track is restricted to the drilling and planing of sleepers, and to the creosoting of soft varieties of wood, which are practised by some companies. Among the treatment which material receives while in service may be mentioned the lubrication of joints carried out by several railways, and also the treatment of the rails in tunnels and along sea costs with pitch, which some companies have done, while one company has the rails and the track accessories treated with paraffin in the same circumstances. In one case we find a reference to the use of check rails in curves of a radius of less than 200 metres (10 chains), in order to reduce wear, and the use of « Cresswell's composition » for filling in old screw holes and spike holes in sleepers.

The information regarding the average life of the various materials is so different that no useful purpose would be served in giving it. It may be remarked merely that according to one of the replies, the wear on the rails is 0.6 lb. per yard per million tons.

All the replies regarding the execution of contract work by the company's employees or the granting of bonuses are in the negative.

Although the figures relating to the maintenance costs leave the same doubts as those given for America and Canada, the following table concerning the companies who have replied is given for reference purposes (see p. 431).

It should be understood that most of the administrations take no special measures to increase the life of material in the case of heavy traffic, the traffic not being very heavy on the greater part of the railways in question. The following measures are taken, however, by some companies, namely: the use of heavier rails, smaller distance between the sleepers, thicker bed of ballast, while the use of guard rails on small radius curves, and crossings of manganese steel are also mentioned in several cases. In addition, a reference is also found to rails of special steel being laid by way of trial, and sorbitic rails in small radius curves.

Length of railway system in kilometres (in miles).	Annual maintenance costs in francs per kilometre (per mile).	Remarks.
602 (374)	18 200 (29 290)	...
1 370 (851)	4 500 (7 242)	For gang expenses only.
	24 000 (38 623)	All in.
1 724 (1 071)	10 700 (17 220)	Per kilometre (per mile) of track.
1 820 (1 131)	11 700 (18 828)	...
1 934 (1 201)	7 400 (1 191)	...
2 036 (1 265)	13 000 (20 921)	...
2 159 (1 341)	31 800 (51 176)	...
2 782 (1 729)	2 400 (3 862)	Per kilometre (per mile) of track.
4 268 (2 652)	10 000 (16 093)	...
4 965 (3 085)	21 400 (34 439)	...
6 179 (3 839)	2 700 (4 345)	For labour only.
6 399 (3 976)	2 700 (4 345)	For the costs of the gangs only.

Conditions of service.

The working day is fixed by statue in South America, in New South Wales, in the Malay States and in the Dutch East Indies. In the countries of South America the working day is 8 hours (48 hours per week); overtime is paid at an increased rate of 50 %, and overtime worked at night on Sunday is paid at an increased rate of 100 %. In New South Wales, the week is 44 hours, overtime being paid at an extra rate. In the Malay States, the maximum working day is 9 hours, while the actual day is 8 hours. In the Dutch East Indies, the ordinary working day is 11 hours, with a maximum of 13 hours; the rest period should be at least 10 hours; in urgent cases, this length of time may be reduced, on condition that, for two consecutive nights, the total break shall be at least 20 hours.

Two administrations keep to the 60-hour limit fixed by the Washington Convention, the obligatory hours of work being fixed in one case, however, at eight hours per day, while in the other case at 52 hours per week.

One administration, by agreement with the workmen, has fixed the working day at 8 hours, extra pay being allowed for overtime.

Other administrations appear to be quite free in fixing the hours of work, which has not prevented a large number of them from fixing the working day at 8 hours. Instances are to be found, however, of 9 to 10-hour days or 52-hour weeks, and one case where the working day is 9 to 11 hours according to the season. The overtime hours are generally paid at a higher rate, in some cases, such hours have to be between 6 p. m. and 6 a. m.

Practically all the companies count the time from the moment the workman has reached the place where work has to begin; in one instance, however, this place should not be more than 4 miles from the station to which he has been appointed.

The only exceptions are two instances where the time is counted from the moment the workman arrives at the gang shed, one case where work is considered to begin from the moment the workman arrives on the railway premises, and another where the work begins as soon as the man leaves his dwelling.

Only one company employs rail motor vehicles to take the workmen to their place of work or for the transport of material, and only on lines where the traffic is not heavy. These vehicles run under the same conditions as the trains. Other companies also employ rail motor vehicles, but only for inspection purposes; one railway uses motor tricycles.

Only in a few rare cases are the men working on the signals and telegraphs provided with means of transport, either rail motor vehicles, or bicycles, which are also the property of the company.

One administration has replied in the affirmative to the question as to the use of graphs showing the progress of work, adding that for each operation a standard time is known.

Appointment and professional instruction of employees.

A large number of the administrations do not merely select the foremen from the gangs but also recruit the inspectors from the ranks of the foremen. No official qualification is required, therefore, while instruction only takes the form of the daily task. As regards the other companies also, the foremen are generally chosen from among the gangers, taking into account their abilities and seniority. One of the colonial railways has men brought from Europe, who are started as foremen, serving at the same time as instructors to those natives who have the ability to reach the same position. One of the replies expressly mentions a course of instruction for the platelayers and the men working on the signals and telegraphs; this course is given once or twice a month for 3 to 5 hours on each occasion.

Several administrations require official qualifications for the inspectors, which does not prevent the inspectors being given during their apprenticeship (about three years) professional instruction according to a very definite programme, divided into three or four periods, after each of which there is an examination. Usually this instruction is entirely practical, without a course of lectures as usually understood. One company, however, gives once a year a course of instruction of one month, attended by about 50 students. There are about 5 hours of lectures daily comprising : morale, permanent way maintenance, supervision, execution of work, drawing, signals and protection devices, regulations and gymnastics. Another encourages correspondence courses by paying the fees for these courses.

Holland.

Organisation of maintenance and inspection.

In Holland, the employees who are responsible for the maintenance of the permanent way are distributed uniformly over the lines, as was pointed out in considering the United States of America and Canada. For the upkeep of bridges, there are not only special skilled workmen, but these workmen are placed under an inspector of bridges. There are about a dozen of these inspectors employed on the Dutch railways, a measure which is due to the large number of moving bridges. There is also a special department for the signals and telegraphs, to which are attached artisans, inspectors, engineers, divisional chiefs.

There are no special watchmen except for the moving bridges, and then only to operate them and not for their supervision.

The level crossings on the main lines are generally guarded, except where there is little traffic on the roads, and where the railway is sufficiently visible from the road (of the level crossings numbering about 2 500, approximately 1 000 are guarded). On secondary lines, the level crossings are not guarded, unless the traffic on the roads is considerable (of the level crossings numbering about 1 300, approximately 200 are guarded).

The regular inspection of the track is made (once daily, except Sunday) by the platelayers. The watchmen are relieved by the platelayers.

An innovation which has helped to make the maintenance of the permanent way more economical, has been to reduce the number of men in a gang.

Permanent way equipment.

On the main lines a rail of 46 kgr. per metre (92.7 lb. per yard) and 18 metres (59 ft. 5/8 in.) long is used. For some little time the joint has been of the suspended type with 4.25 mm. (11/64 inch) bolts; during the last few years a supported joint has been laid, wedged in a cast iron chair, constructed so that the fishplates, which are provided with two bolts, only become wedged together when the joint is carrying the load of a wheel, while expansion at the rail ends can take place freely when there is no load on the joint. The rail rests on cast iron chairs weighing 13 kgr. (28.7 lb.) each and is secured to the chairs by bolts and clips, the chairs being fixed to the sleepers by means of four coach screws. Owing to the large surface offered by the chairs (630 cm^2 = 97.6 sq. inches) the sleepers are of pine; 24 sleepers are laid over a length of 18 metres (59 ft. 5/8 in.), which number is increased, however, to 30 for lines where the traffic is heavy.

For less important line tracks, a rail of 42 kgr. (84.7 lb. per yard) is used, attached to oak or beech sleepers by means of a poplar sole-plate with coach screws (the « Est » system); for sidings and also for some lines where the number and speed of the trains is not great, a rail of 38 kgr. (76.6 lb. per yard) is used, attached to sleepers, preferably of hard wood, and which are provided with sole-plates, by means of spikes. Finally, for lines of secondary importance, a rail weighing 34 kgr. (68.5 lb. per yard) is used, the sleepers and attachment being the same as for the 38-kgr. rail. The bed of ballast, which is at least 20 cm. (8 inches) thick under the sleepers, is composed of gravel, the use of hard broken stone not having been introduced as yet for financial reasons.

Strength of gangs for the maintenance of the permanent way.

The length of track attended to by one gang varies on the main lines from 7 to 8 km. (4.35 to 5 miles); the minimum number of men in a gang is 5, including the foreman. The strength of each gang is given in the following table (see p. 434).

The number of men in each gang as calculater according to this table should be increased by a number of men equivalent to the time required to relieve the watchmen. The total is the standard effective of the gang necessary for the ordinary maintenance of the permanent way, irrespective of any special work (such as important renewals of tracks).

Number of trains per day	Double track lines.		Single track lines.		In the stations. Length of track in metres *(in miles)* per workman.
	Number of workmen per km. *(per mile)* of double line.	Length of track in metres *(in miles)* per workman.	Number of workmen per km. *(per mile)* of single line.	Length of track in metres *(in miles)* per workman.	
		Main lines.			
Less than 20	1 (1.6)	2 000 (1.243)	2/3×1 (2/3×1.6)	1 500 (0.932)	2 000 (1.243)
From 20 to 40	1.1 (1.77)	1 820 (1.131)	2/3×1.1 (2/3×1.77)	1 365 (0.848)	1 820 (1.131)
From 40 to 70	1.2 (1.93)	1 665 (1.035)	2/3×1.2 (2/3×1.93)	1 250 (0.777)	1 665 (1.035)
From 70 to 100	1.33 (2.14)	1 500 (0.932)	2/3×1.33 (2/3×2.14)	1 125 (0.699)	1 500 (0.932)
More than 100	1.5 (2.4)	1 335 (0.829)	2/3×1.5 (2/3×2.4)	1 000 (0.621)	1 335 (0.829)
		Secondary lines.			
Less than 20	0.9 (1.45)	2 200 (1.367)	5/9×0.9 (5/9×1.45)	2 000 (1.243)	2 200 (1.367)
From 20 to 40	1 (1.6)	2 000 (1.243)	5/9×1 (5/9×1.6)	1 800 (1.118)	2 000 (1.243)
From 40 to 70	1.15 (1.85)	1 730 (1.074)	5.9×1.15 (5/9×1.85)	1 565 (0.972)	1 730 (1.074)
More than 70	1.3 (2.1)	1 530 (0.951)	5/9×1.3 (5/9×2.1)	1 385 (0.861)	1 530 (0.951)

The following procedure is employed to convert goods lines, sidings, and turnouts into main line track :

1 m. of main track . . . . = 1 m. of main track.
1 ordinary turnout or crossing . . . . = 100 m. (109 yards).
1 slip points (single) . . . . = 150 m. (164 yards).
1 slip points (double) . . . . = 200 m. (218 yards).
For goods tracks and their track appliances, 2/3 of the above values.
For important sidings and their appliances, 1/2 of the above values.
For less important sidings, and their track appliances, 1/3 of the above values.

In winter, the number of men is reduced as much as possible, the reliefs always requiring a certain number, while the effective has never to be less than 1 foreman and 4 platelayers. Only the permanent employees of the railway, therefore, remain on duty during the winter. In summer, the gangs are made up by temporary workmen. The number of the latter is calculated as follows :

There is a certain difference between the amount of wages to be paid to a standard gang and that of the wages paid to the reduced gang in winter. Half of this difference may be spent in summer for temporary workmen. This method results in a saving in labour, not only because no more temporary workmen will be engaged than are necessary, and because the wages of these workmen are less than those of the permanent employees of the railway, but also because the engineers in charge of the sections are able to distribute the temporary workmen according to the needs of the moment.

The gangs have to clean the ditches, look after the hedges, and clear away locomotive ashes. The cleaning of ditches is only given out to contractors in a few special cases.

Method of maintaining the permanent way.

On the Dutch railways, the method of periodical overhaul is the rule; the method of maintenance by investigation is the exception. The general inspection is usually carried out every two years; it is done by the ordinary gangs.

Only the sleepers are subjected to any preparation by creosoting before being put in the track; the sleepers provided with cast iron chairs and the « Est » type sleepers are previously adzed and drilled.

Considerable care is bestowed on the material in service. For the purpose of keeping the fish-joints in good repair, the bearing surfaces are lubricated, while on the appearance of a worn place on these surfaces, small pieces of sheet metal, 1, 2 or 3 mm. (0.0395 — 0.079 or 0.118 inch) thick according to the gap which has appeared, are applied. The fish-plate bolts are tarred in order to protect the thread. The same is done to the bolts securing the clips which fix the rail to the cast iron chair. When the sole-plates have been forced too deeply into the sleepers or when the slope is not correct, the seating is adzed and the old spike holes are plugged. The poplar sole-pieces of the « Est » system are replaced when split. Very great care is taken to make sure that the coach screws, securing the cast iron chairs to the sleepers, are driven well home, so that the chair and sleeper are joined as tightly as possible. In general, every precaution is taken to avoid as much as possible any mutual movement between the various parts of the permanent way proper.

Statistics relating to the life of material (mainly as regards the sleepers) have not been kept long enough to be able to draw sufficiently correct conclusions. On the grounds of practical experience, however, one may say that the rails remain 20 to 25 years in the main line tracks, after which they do further service in sidings, very often after the ends have been removed in order to form a new fish-joint. It is reckoned that pine sleepers fitted with cast iron chairs will last at least 25 years (there are some lines with very heavy traffic which are 17 years old, and of which only a very small percentage of the sleepers have had to be renewed), while pine sleepers protected by ordinary plates have an average life of 15 years. For sleepers of hard wood (oak and beech) protected by sole-plates, 20 to 25 years is reckoned.

The work connected thereto (such as renewing the track, rails and sleepers, or replacing sleepers over considerable lengths) is carried out with bonuses. In order to fix the amount of the bonuses, a unit is established for the work a man can do in a day under normal conditions, without receiving a bonus, while by taking into account the total wages, it is possible to calculate the cost p of the unit. In order to ascertain the unit, a gang working normally is observed unknown to the men; after several observations, enough information is obtained to establish the unit in different conditions. A number m of men working n days have to produce mn units of work. For every unit above this amount, a bonus of 1/2 p is awarded. The total bonus is distributed among the men according to the time they have worked (there are always some men who have to leave the work for a part of the day in order to relieve the watchmen), the foreman's time being counted double.

It is the ordinary gangs, reinforced by temporary workers or even by men of another gang who perform work for bonuses, the foreman himself directing and supervising the work, for the maintenance of which he will later be responsible; it is in his interests, therefore, to see that the work is well done. Moreover, the inspector of the permanent way supervises the work closely. It has not been found, therefore, that bonus work is done less well than other work.

Although there are some instances where the employees have not been able to make certain of their bonus, the results are generally very satisfactory both for the men and for the company.

The annual maintenance costs per kilometre of single main line track are 2 200 florins (3 540 fl. per mile). This figure includes the wages and the material for the maintenance of the permanent way. The maintenance of the signals etc., costs 285 florins per kilometre (458.5 fl. per mile).

As regards the special measures for increasing the life of the material in the case of heavy traffic, mention should be made — apart from the use of heavy rails — of the increase in the number of sleepers, the normal number of 24 on a length of 18 m. (59 ft. 5/8 in.) being raised to 30 when the traffic is very dense.

Conditions of service.

The statutary average for the duration of work of platelayers is 102 hours per fortnight, which corresponds to a day of 8 1/2 hours, the men being entitled to one day off a week. The administrations have the power of increasing the time in summer and of diminishing it in winter so that the average remains fixed. Proceeding in this manner, the day is 9 hours in summer; in winter it is 7 hours with a few variations. No difference is made between ordinary time and overtime, it being possible to extend the workng day to 10 hours or even more in case of urgency, provided that the average of 102 hours a fortnight is not exceeded.

The time of beginning work is counted from the moment the workman arrives at the place where the work is to be done. The workmen have to use their own means to get there, no motor vehicles being placed at their disposal.

The men working on signals and telegraphs, where they are responsible for keeping the appliances in order, use their own bicycles, for the upkeep of which they receive an allowance.

Graphs to show the progress of work with information regarding the economic results of the work are not employed.

Appointment and professional instruction of the employees.

The foremen are selected from the ranks of the platelayers, their character, knowledge and capabilities being taken into account, and care being taken that a foreman is never appointed to a gang in which he has worked as platelayer.

As regards the permanent way inspectors, they are required to have passed successfully certain courses, ensuring that their education is satisfactory; when they satisfy this condition they are allowed to sit for a competitive examination. On passing this successfully they are appointed « inspector cadets », and as such they are required to serve a term of three years' apprenticeship, during which they are attached to a permanent way inspector, to several offices, to the permanent way construction workshop, etc. On completing their apprenticeship, they have to sit for another examination comprising the technical branches they have to deal with, and the administrative knowledge required. If the result of this examination is satisfactory, the way is open to them for appointment as inspector.

The administration does not assist in the instruction of this staff beyond placing the apprentices under chiefs who may be expected to devote themselves to the instruction of the young men placed under their charge.

CONCLUSIONS.

1. All the administrations who have replied to the questionnaire possess a staff of workmen uniformly distributed over the lines considering always the different conditions. The maintenance of structures, such as tunnels, bridges, etc. by a special staff of workmen is fairly general.

2. The regular inspection of the track is carried out in almost every instance by the platelayers, who also generally relieve the watchmen.

3. No outstanding innovations intended to render the maintenance of the permanent way more economical have been introduced in recent years.

4. The use of formulæ for determining the number of workmen required for the maintenance of a certain length of track is not as extensive as this eminently useful method deserves to be.

5. It is a very common practice to vary the number of workmen in a gang according to the season.

6. Maintenance by general overhaul is not applied except in Holland.

7. Bonuses are not granted for work done except in Holland.

8. The hours of work for platelayers vary; nevertheless, the 8-hour day is fairly common.

9. The time of work begins to be counted almost uniformly, either at the moment when the workman is at the place where the work is to begin, or at the moment when the workman arrives at the shed of the gang, in the latter case with the object of being conveyed to the place of work in a rail motor vehicle.

10. Rail motor vehicles for conveying the workman to his place of work are not in general use except in the United States of America and Canada.

11. The artisans and the men working on signals are very often provided with means of transport, either bicycle or rail motor vehicle.

12. The administrations who possess lines with considerable traffic are making efforts to increase the life of the material by special measures.

13. No administration uses graphs of the progress of the whole of the works, showing their economical results.

14. The foremen are generally recruited from the ranks of the platelayers. while as regards the inspectors, they are almost always required to possess a diploma, ensuring that they have had a satisfactory education, the professional education being obtained in practice. Courses of instruction are given only in a few rare cases.

APPENDIX A.

Detailed questionnaire relating to question IV.

Recent improvements in the mechanical appliances and the scientific organisation of permanent way maintenance.

FIRST PART.

Recent improvements in the mechanical appliances for the maintenance of the permanent way.

1. — Have you introduced or improved in recent years mechanical appliances for the maintenance of the permanent way? If so, how long have you adopted them?

Do you employ mechanical appliances for the following operations :

a) Removing the track from the formation;

b) Loading, transport and unloading of ballast;

c) Loading and unloading rails and sleepers;

d) Spreading and rolling the ballast;

e) Unloading and laying completely assembled sections of line;

f) Transport of material along the track;

g) Drilling and adzing sleepers;

h) Distributing and laying sleepers;

i) Laying rails;

j) Fixing the coach screws of the chairs or sole-plates to the sleepers;

k) Tightening the bolts at the joints or other portions of track equipment;

l) Levelling the ballast;

m) Lining up and levelling the track and packing the ballast;

n) Weeding and cleaning the ballast, either for the whole of its width or only between the sleepers;

o) Straightening, drilling and cutting rails?

p) For what other purpose?

Do you employ special vehicles for the transport of material?

2. — If such appliances are used, please give a description of the appliances in use, explained by drawings, sketches or photographs, and all the parts which you consider necessary to make the description perfectly clear.

3. — Please indicate the cost of purchasing and installing these appliances, and the working expenses.

4. — What saving results from the use of these appliances, taking into account the cost of labour, accessory equipment, lubrication, interest and depreciation on the capital expenditure, etc.?

How many men are required to operate the appliances?

5. — Please indicate the minimum length of track above which the operation of mechanical appliances would be of interest or economical.

6. — If very little saving has been effected, what are the other advantages which have led to the introduction of mechanical appliances, for example a comparison of the time required to carry out the work by one or the other method under average or normal conditions.

7. — If such appliances are employed on the line, what is the source of power?

Can it be used when the line in question is in service?

Can it be transported without blocking up the tracks in service?

To what distance is work possible without moving the source of power?

SECOND PART.

Scientific organisation of the maintenance of the permanent way.

1. — What is the organisation of the maintenance of the permanent way on your system?

A. — Organisation of the employees in charge of maintenance :

a) Are they uniformly distributed over the lines?

b) Are they concentrated in definitely selected places?

c) Have you a staff of workmen specially engaged in the maintenance of special works and structures, such as tunnels, bridges, etc.?

B. — Supervision and guarding of the track :

a) Have you watchmen for certain portions, such as tunnels, bridges, etc.?

b) Are all the level crossings guarded or in what circumstances are they guarded?

c) Have you special watchmen for the regular inspection of the track or is this inspection made by the platelayers?

Are the watchmen relieved by the platelayers?

2. — Have you introduced into the organisation in recent years any innovations intended to effect the maintenance of the permanent way more economically?

3. — What is the most recent equipment of your main line tracks, the weight and length of rails, the system of joints, number and nature of the sleepers, method of fixing the rails to the sleepers, quality of ballast?

4. — What is the average length of track maintained in repair by a gang on the main lines? What is the number of platelayers in a gang, including the foreman?

5. — Do you employ formulæ to determine the number of workmen required for the maintenance of a certain length of line (single line or several lines)? If so, what are these formulæ?

How do you introduce into these formulæ the length of accessory tracks and the number of points, equivalent to a certain length of main line track?

6. — Is the number of workmen in a gang constant winter and summer, or have you gangs formed of a restricted number of workmen who are on the establishment of your railway, supplemented by temporary workmen in summer?

7. — What other occupations are they engaged in, such as cleaning ditches, repairing hedges, etc., or is such work entrusted to contractors?

8. — For the maintenance of your permanent way, do you employ the system of maintenance by investigation, or general periodical overhaul?

In the last case, after what interval of time is the general overhaul repeated?

9. — If maintenance is by general overhaul, do you have this work carried out by the ordinary gangs or by special gangs overhauling the entire permanent way?

10. — What is the technical procedure for :

a) the preparation of the material before it is placed in the track;

b) the care bestowed on the material while in service, giving the average life of the different classes of material;

c) laying in the curves;

d) packing and aligning the track;

e) cleaning and weeding the ballast?

11. — Do you have certain work done by contract by your own workmen, or do you grant bonuses for work carried out in a certain time?

If so, what are these bonuses, expressed in terms of the workmens' wages?

Has the method of having maintenance work done by contract or with the grant of bonuses any ill effect on the way the work is carried out?

What are the annual maintenance costs per kilometre of single main line track?

12. — What are the working hours of the watchmen, the ordinary platelayers, etc.? Are the hours fixed by statute?

If so, has any distinction been made between ordinary work, extraordinary work and urgent work?

13. — If the hours of work are fixed by statute, does the time worked begin to be counted as soon as the workman is at the place where work is to begin, or from the moment the workman arrives on the territory of the railway at the nearest point to his domicile, or when he arrives at an assigned place, for example a station?

14. — Do you employ rail motor vehicles to convey the workmen to their place of work? Give the conditions under which these vehicles are run.

15. — Are the artisans (carpenters, painters, masons, etc.), and the employees working on the signals and telegraphs provided with means of transport, either bicycles or rail motor vehicles?

If so, are the bicycles the property of the railway administration, or do they belong to the employees, who receive and allowance for their maintenance?

16. — Do you take any special steps to increase the life of the materials in the case of heavy traffic?

17. — Do you employ graphs showing the progress of all the works mentioned and indicating their economical results?

If so, have you determined and established by graphs, by means of close observation of the operations carried out on your lines, the normal, the standardised time required for each individual operation or for all the important work to be carried out on the track equipment, for example:

a) Loading and unloading of 1 ton of rails;

b) Loading and unloading of 1 cubic metre of ballast, etc.;

c) Renewing 1 metre length of rails;

d) Packing 1 sleeper in different kinds of ballast;

e) Lining up 1 metre length of track, both in plan and elevation;

f) Renewing 1 sleeper in a main line track and in a siding;

g) Renewing 1 cubic metre of ballast;

h) Weeding 1 metre length of track;

i) General inspection of 1 metre length of track;

j) Renewing 1 metre length of complete track.

In fixing the standardised, normal operations, in what manner have you taken account of the loss of time due to the traffic or to other causes?

18. — How do you select the employees in charge of the maintenance of the permanent way, that is to say, the inspectors and foremen?

Are these employees required to possess an official or professional qualification?

Does the administration facilitate the instruction of these employees?

If so, indicate the organisation of these schools.

Appendix B.

Summary of replies received to the questionnaire.

—		Administrations					
		consulted.			who replied.		
		Number.	Km.	Miles.	Number.	Km.	Miles.
I. — *United States of America and Canada.*							
United States of America		22	74 982	46 592	12	46 438	28 856
Canada		2	36 979	22 978	1	36 503	22 682
		24	111 961	69 570	13	82 941	51 538
II. — *Great Britain and Ireland.*							
Great Britain and North of Ireland		15	33 923	21 079	10	32 115	19 956
Irish Free State		1	3 520	2 187	...	...	...
		16	37 443	23 266	10	32 115	19 956
III. — *South America, India and the British Colonies, Dutch Colonies, China and Japan.*							
Argentine	South America	9	33 326	20 708	4	16 826	10 455
Brasil		3	6 847	4 255	...	...	...
Chili		3	2 235	1 389	...	...	..
Salvador		1	161	100	...	...	...
Uruguay		2	1 759	1 093	1	1 577	980
Africa	India and British Colonies.	6	27 319	16 976	5	26 555	16 501
Australia		3	18 010	11 191	2	13 941	8 663
Ceylon		1	1 370	851	1	1 370	851
India		11	50 293	31 251	7	39 172	24 341
Malay States		1	1 724	1 071	1	1 724	1 071
Mesopotamia		1	1 218	757	...	...	...
Dutch Colonies		3	5 433	3 376	1	4 182	2 599
China		4	4 732	2 940	1	1 111	690
Japan		2	14 803	9 198	1	2 159	1 342
		50	169 230	105 156	24	108 617	67 493
IV. — *Holland.*							
Holland		4	3 823	2 376	2	3 654	2 270
		94	322 457	200 368	49	227 327	141 257

[621. 132.8]

REPORT No. 3

(**Europe, except France**)

ON THE QUESTION OF RAIL MOTOR CARS (SUBJECT XX FOR DISCUSSION AT THE ELEVENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION) (1),

By Z. ZAVADJIL,

Engineer, Chief of the Locomotive Department at the General Headquarters of the Yugoslavian State Railways.

Figs. 1 to 12, pp. 459 to 471.

The questionnaire reproduced in Appendix I was addressed to the following twenty-two railway administrations :

1. Belgian National Railway Company.
2. Bulgarian State Railways.
3. Greek State Railways.
4. Piræus - Athens - Peloponnesus Railways, Greece.
5. Polish State Railways.
6. Portuguese State Railways.
7. Portuguese Railway Company, Portugal.
8. Rumanian State Railways.
9. Swiss Federal Railways.
10. Czechoslovakian State Railways.
11. Italian State Railways.
12. Danish State Railways.
13. Finnish State Railways.
14. Norwegian State Railways.
15. Netherlands Railway Company.
16. Swedish State Railways.
17. Great Western Railway, Great Britain.
18. London Midland & Scottish Railway, Great Britain.
19. London & North Eastern Railway, Great Britain.
20. Great Southern Railway, Ireland.
21. Madrid to Saragossa & Alicante Railways, Spain.
22. North of Spain Railways.

Five of these administrations replied that they had no rail motor-cars, viz.:

1. Belgian National Railway Company;
2. Bulgarian State Railways;
3. Greek State Railways;
4. Madrid Saragossa & Alicante Railways, Spain;
5. North of Spain Railways.

Two administrations (Swedish State Railways and Portuguese State Railways) answered that they had not sufficient data for a reply; three administrations (Czechoslovakian State Railways, Norwegian State Railways, London Midland & Scottish Railway) have delayed their replies, and from five administrations we have received no reply.

The eight other administrations have supplied us with detailed replies on their rail motor-cars in service or on test. These replies are summarised in the tables — Appendix II.

These administrations are the following :

1. Italian State Railways;
2. Danish State Railways;

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(1) Translated from the French.

3. Netherlands Railways;
4. Finnish State Railways;
5. Rumanian State Railways;
6. Swiss Federal Railways;
7. Yugoslav State Railways;
8. London & North Eastern Railway.

I. — Types and principal data of rail motor-cars in service.

These eight administrations have in service or on test the rail motor-cars shown in table 1 below:

TABLE 1.

Railway Administration.	Petrol.		Diesel engine.		Steam.	Total.
	Transmission					
	Mechanical.	Electric.	Mechanical.	Electric.	Mechanical.	
1. English	1	1	...	...	55	57
2. Danish	40	...	...	6	...	46
3. Dutch	13	...	8	...	...	21
4. Rumanian	...	21	...	...	...	21
5. Italian	2	...	...	2	...	4
6. Finnish	2	...	...	1	...	3
7. Swiss	2	...	...	1	...	3
8. Yugoslav	2	...	...	...	...	2
Totals	62	22	8	10	55	157
	84		18		55	
Per cent	40 %	14 %	5 %	6 %	35 %	100 %
	54 %		11 %		35 %	100 %

It will be seen that the administrations cited possess altogether 157 rail motor-cars, of which:

1. — 84, or 54 %, have petrol engines, 62, or 40 %, of these having mechanical transmission and 22, or 14 %, electric transmission;

2. — 55, or 35 %, of the cars are steam driven with mechanical transmission (by gearing or chain), or with engines driving the wheels direct. It is interesting to note that all the steam rail motor-cars are English cars, the last having been ordered in 1928, and that no Continental Administration at present reports having steam motor-cars;

3. — In the third place come the rail motor-cars with Diesel engines, to the

number of 18 (11 %), of which 8 (5 %) have mechanical transmission and 10 (6 %) electric transmission.

It is interesting also to compare these data with those supplied in the report of Mr. L. Greppi of 1909 (¹), i. e. 20 years ago.

Mr. Greppi's data are as follows :

95 % — 185 steam rail motors-cars,
3.5 % — 7 petrol » » »
1.5 % — 3 electric » » »
with accumulators.

It will be seen that during these last twenty years the relative number of steam rail motor-cars has diminished considerably, that the petrol cars are now the most numerous, that the electric accumulator cars, which in any case were few in number, are no longer in use, while a new kind of cars has been introduced which did not exist before, i. e. the Diesel engine cars.

Number and arrangement of axles.

The rail motor-cars of which we know the characteristics have 2, 3 and 4 axles: according to table 2 the most numerous are the 2-axle cars.

TABLE 2.

No of rail motor-cars.	Petrol.	Diesel engine.	Steam.	Total.
2-axle . . .	65	14	...	79
3-axle . . .	2	...	...	2
4-axle . . .	15	4	...	19
Total . .	82	18	...	100

It can be seen that there are 79 (79 %) 2-axle rail motor-cars — the majority of these are petrol driven — (65 % petrol driven against 14 % Diesel engine). Then come the 4-axle cars, there are 19 (19 %) of these, of which 15 % are petrol driven and 4 % Diesel engined, then the 3-axle cars, amongst which there are only 2 petrol cars (2 %), belonging to the Danish Railways.

Consequently, without making any distinction between the motors, the great majority, nearly 4/5ths of all the cars, are of the light 2-axle type. For the English steam cars we have no data available with regard to the number of axles.

According to table 3, the rail motor-cars are to be classed as follows from the point of view of weight :

a) Petrol cars: from 16.7 t. (16.4 Engl. tons) (on the Yugoslavian Railways) to 40.4 t. (39.8 Engl. tons) (Dutch Railways);

b) Diesel engined cars: from 22 t. (21.7 Engl. tons) (on the Dutch Railways) to 63 t. (62 Engl. tons) (on the Swiss Railways).

Comparing these figures with those of 1909, we see that the minimum weight of the rail motor-cars has slightly increased (16.7 t. [16.4 Engl. tons]) instead of 14.4 t. (14.2 Engl. tons), while the maximum weight has slightly decreased (40.4 t. [39.8 Engl. tons]) in the case of the Dutch petrol cars instead of 48 t. (47.2 Engl. tons) for the steam rail motor-cars of 1909). It will be seen that we are not considering here the data concerning the Diesel engined motor-car of 250 H.P. of the Swiss Railways, which is, with its weight of 63 t. (62 Engl. tons), exceptionally heavy.

The power of the engines of the rail motor-cars varies between a minimum of 60 H.P. (petrol cars of the Rumanian

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(¹) *Bulletin of the International Railway Congress Association*, March 1910, page 1273.

Tab

Weights and pow

RAILWAY.			Total weights in metric tons. Q.	Number of axles.	Number of cars.	Effective H. P. N.
English :	Steam		31.18	...	24	...
			34.15	...	20	...
			35	...	11	...
—	Petrol		20.5	...	1	105
			31.4	...	1	70
Danish :	Petrol	M*a*	13.9	2	40	100
		M*c*	23.8	3		
		M*e*	17.0	2		
		M*f*	1[illegible].5	2		
—	Diesel engine	MR	45	4	6	180
Dutch :	Petrol	I	40.4	4	13	70
		II	40 2	4		
—	Diesel engine		22	2	8	75
Rumanian :	Petrol		18.9	2	21	60
			19.9	2		70
			21.8	2		90
Italian :	Petrol		23	4	2	...
—	Diesel engine		21	...	2	...
Finnish :	Petrol		23.8	2	2	75
—	Diesel engine		38 2	4	1	90
Swiss :	Petrol		26 2	2	2	120 100
—	Diesel engine		63.0	4	1	350
Yugoslav :	Petrol		16.7	2	2	85
Daimler petrol rail motor cars of the year 1909			20	2	...	30

rail motor-cars.

umber seats. m.	Maximum permissible speed. Km./h.	H. P. of motor per metric ton of weight. $\frac{N}{Q}$	Total weight per seat. $\frac{Q}{m}$ in kgr.	Weight and power of rail motor cars according to report of 1909.
...	...	...	...	
...	...	...	...	
...	...	...	. .	
...	66	5 12	. .	
...	64	2 83	...	
24	70	7.2	580	
50	70	4.2	480	
33	70	5.9	520	
33	75	5.4	560	
60	70	4.0	750	
85	60	1.73	475	
67	...	1.74	328	
48	45	3.16	394	
	50	3.5	415	
60	65	4.12	365	
70	50	...	400	
46	50	...	455	
42	45	3 14	568	
62	56	2 35	615	
48	60	3.82	546	
50	75	3.97	1 160	
52	65	5.07	320	
64	30	1.5	310	

RAIL MOTOR CARS OF 1909 :

Weight :	2 axles	14.4 — 24.2
	3 —	23.6 — 32 8
	4 —	42 5 — 48.0
Power :	35 to 180	200 H. P.

Railways of 18.9 t. [18.6 Engl. tons] — total weight) to a maximum of 180 H.P. (Diesel engined cars of the Danish Railways of a total weight of 45 t. [44.3 Engl. tons]). We are not considering here the exceptional car already cited of the Swiss Railways.

The majority of the cars with internal combustion engines (i. e. 93 %) have engines of 70 to 100 H.P. Only 6.5 % of all these cars have engines more powerful than 100 H.P., and one Swiss car already mentioned has a Diesel engine of 250 H.P.

The comparison of these figures with the data for the Daimler rail motor-car with petrol drive, of 1909, shows us that the power of the engines for rail motor-cars has increased from 30 to 100 H.P. and more, the maximum speed of 30 km. to 65 km. (18.6 to 40.4 miles) per hour; as to the number of passenger places, we see that it remains practically the same.

The comparison of the modern petrol and Diesel rail motor-cars with the steam rail motor-cars is unfortunately impossible, because we have no data concerning the power of the steam engines of the modern English rail motor-cars.

But the comparison with the data concerning the steam rail motor-cars of 1909, provided with engines of very variable power (from 30 to 180-200 H.P.), shows us that the power of the engines of the modern rail motor-cars is much more standardised, since the majority of the cars have engines of 70-100 H.P.

The following columns of the same table show us the number of passenger places in the rail motor-car itself, the maximum speeds of which they are capable, the power of the engine per metric ton of weight of the car, and the total weight of the cars per seat. Of these two last-named quantities, the first shows the power of the engine with relation to the weight of the car.

Naturally, the larger this figure is the more power there is available for the increase of the speed or for the increase of the tractive power of the car.

It will be seen that these figures vary from a minimum of 1.75 for the Dutch petrol cars to a maximum of 7.2 for the Danish petrol cars with mechanical transmission.

The majority of the cars in this table have figures included between 3.0 and 3.5 H. P. per tonne of total car weight.

Seeing that the maximum speed of which the Dutch and English rail motor-cars are capable is approximately the same (60 km. [37.3 miles] as against 66 km. [41 miles] per hour), we might conclude that the efficiency of the Dutch cars is much superior to that of the English cars, which is naturally very improbable.

The other possible supposition is that the English cars have a greater tractive power than the Dutch cars. From the data relative to the service of these cars (see Part II of this Report), we see that this second conclusion is entirely just, because the English cars have been able to haul several trailers, while the Dutch rail motor-cars can only be coupled with one van between two motor-cars.

The last column of the table shows us the total weight of the rail motor-car relatively to the number of passenger seats.

This figure characterises the relative lightness of these various cars.

It will be seen that this figures vary between the minimum of 320 kgr. (705 lb.) for the petrol cars of the Yugoslav Railways, and of 328 kgr. (723 lb.) for the Diesel cars of the Dutch Railways, to the maximum of 615 kgr. (1 355 lb.) for the Diesel cars of the Finnish Railways and 750 kgr. (1 653 lb.) for the Diesel cars of the Danish Railways.

It will be noted that we are not taking into consideration the very heavy car of the Swiss Railways, the relative weight of which, 1 160 kgr. (2 557 lb.), is exceptionally high.

We may then, from the data studied, consider the average relative weight of a modern light rail motor-car as equal to 400 to 500 kgr. (880 to 1 110 lb.).

The comparison of these data with those for the old Daimler petrol car shows us that this car, relatively to its weight, was of very low power, since it had only 1.5 motor H.P. per tonne; its speed was only 30 km. (18.6 miles) and its relative weight was 310 kgr. (680 lb.) per passenger seat.

From the remarks in table 2 it can be seen that the majority of the steam rail cars of 1909 had much more powerful engines (up to 180-200 H.P.), than the modern cars with internal combustion engines.

The comparison between the petrol cars and the Diesel cars shows us that the two engine systems, from the point of view of application to railway cars, are approximately the same (excluding the exceptional car of the Swiss Railways).

This must be regarded as a considerable success of modern technique, which has succeeded in designing a Diesel engine as light and at the same time as reliable as the modern petrol motor.

The motors and the transmission of the motion to the driving wheels.

Table 4 shows us the data relative to the internal combustion engines of the rail cars considered.

We see that the great majority of the engines, whether petrol or Diesel, are of the 6-cylinder vertical type with a speed of some 1 000 r.p.m. According to the data, these are the motors of heavy type used on motor lorries and agricultural tractors. The only exceptions are the following :

a) the petrol motors of the Roumanian Railways of 60 and 70 H.P., which have only four cylinders, and

b) the Diesel engine of the Swiss Railways, with eight V-mounted cylinders — 90°, slow speed, 550 r.p.m.

The petrol motors of the Danish Railways have the highest r.p.m.; this is 2 000, and thus approaches the r.p.m. of the light motor lorry.

We have, unfortunately, very few details of the motors in question, and therefore we cannot study them in a detailed manner.

We know that the question of the transmission of the motion of the motor to the driving wheels is of the greatest importance for the application of internal combustion engines to railway service.

The fact is established that this question has so far been solved in the following manner :

1. Purely mechanical transmission;
2. Electrical transmission;
3. Pneumatic transmission.

We are not citing here the isolated systems of hydraulic and oil-pressure transmission.

According to the data in table 4, we see that the rail motor-cars examined only respond to the first two solutions of this question, i.e. they are provided either with mechanical or electrical transmission, the mechanical transmission being of the motor-car type, pure or modified.

Table 1 of this Report shows us that the majority of the petrol motors have mechanical transmission (62 cars out of a total of 84); amongst the Diesel engined cars these numbers are divided almost into two equal parts, with a slight prefe-

TABL

Motors and transmission c

RAILWAY.	Motors.				
	Dimensions D×S mm.	Numbre of cylinders.	R. p. m. n.	Effective H. P.	Weight of motor (kgr.
Rumanian, petrol	140×160 150×180 140×160	4 4 6	950 1 100 1 050	60 70 90	... .
Dutch :					
Petrol I	...	6	1 200	70	...
Petrol II	...	...	...	...	...
Diesel III	...	6	1 100	75	...
Yugoslav, petrol	130×160	6	1 000	85	...
Danish :					
Petrol.	...	6	2 000	100	500 (motor onl
Diesel	...	6	950	180	2 500
Italian :					
Petrol.	...	...	...	...	...
Diesel	...	...	...	...	...
Swiss :					
Petrol.	...	8	1 000	105	...
Diesel	...	8	550	250	6 500
Finnish :					
Petrol.	...	6	...	75	...
Diesel	...	6	...	90	...

otion to driving wheels

Maker.	Power transmission mechanical.	 electric.
Westinghouse. De-Dion. Westinghouse.	...	Motor H. P. — 60 — 70 — 90 Compound Dynamo, KW. — 45 — 45 — 60 Tension, V. — 500 — 500 — 550 Capacity, A. — 90 — 90 — 118 Number of motor units (series type). — 2 — 2 — 2 H. P. — 35 — 35 — 50
N. A. G. Berlin.	4-speed transmission A. E. G. type; gearing always in mesh; clutch controlled by compressed air.	...
...	...	...
M. A. V.	4-speed transmission, D. G. G. type, Hannover; gearing always in mesh; clutches controlled partly mechanically, partly by compressed air.	...
Ganz, Budapest.	4-speed transmission: gearing always in mesh; multiple-disk clutches.	...
...	3 and 4 speeds in both directions.	Generator 120 kw. shunt, continuous current. Two on same bogie, 190 amp., 550 volts; 1 200 r. p. m. Speed regulation by generator shunt control.
...	Automobile type change speed gear.	...
hw. Lok. und Masch. Fabr., Winterthur, Sulzer Bros., Winterthur.	4-speed transmission Saurer-Arbon system, oil pressure clutch.	... Brown — Boveri & Co., Baden, electrical plant. Two motors, one on each bogie.
A. E. G., Berlin.	Automobile type change speed gear, one driving axle.	...
« Diesel-electr. Vesteräs A.B. »	...	Continuous current generator; two motors, one on each axle.

rence for electrical transmission (since of the total number of 18 cars, 10 have electrical and 8 mechanical transmission).

These data show us that for modern rail motor-cars with petrol drive mechanical is preferable to electrical transmission, as being simpler and cheaper.

This solution is thus the same as for the modern road motor-car.

As to the Diesel engine, which is not so flexible in service as the petrol engine, we see that practice has demonstrated that the two systems of transmission are good, since they are employed almost equally.

The comparison between the numbers of transmissions on the two systems, without having regard to the class of motor, shows us that almost three-fourths of the rail cars have mechanical transmission, which is quite natural, in view of the much greater number of petrol cars in use.

We shall see further on that the application of electrical transmission is the cause of a considerable increase in the cost of the rail motor-car.

We can, then, establish the fact that *the modern petrol rail cars have mechanical transmission, and the Diesel rail cars have both systems of transmission. At the same time, electrical transmission is, in sum, greatly in the minority.*

As regards the modern steam rail cars, we learn from the reply of the English railway administration, the London & North Eastern Railway, that the steam rail car has been much transformed since 1909, at which period the steam cars had engines driving direct on to the driving wheels.

The English Sentinel steam cars, which represent 80 % of all the cars on this railway, have mechanical transmission between the steam engine and the driving wheels, nearly half by gearing and the other half by chain (24 : 20); the remaining Clayton steam cars, representing the other 20 %, have the engine driving the axles direct.

In this way, the engine of the steam car runs at a much higher speed, and can be more light and economical than the old engine of the 1909 rail car.

The boiler pressure has remained practically unaltered; in fact, the majority of the old steam rail cars ran at a pressure of 18 to 20 atm. (256 to 284.5 lb. per sq. inch), and the boilers of the modern cars have a pressure of 19.25 to 21.0 atmospheres (273.8 to 298.7 lb. per sq. inch).

It should be remarked that we are not taking into account here the exceptional boilers of the Serpollet system, which worked at steam pressures up to 40-60 atm. (569 to 853 lb. per sq. inch), and which are no longer used.

The same table 4 shows that nearly all the cars with mechanical transmission have this transmission by moving gear trains on a modified motor-car system.

The difference between the two systems consists essentially of the fact that the gears of the mechanical transmission of a rail car are always engaged, and are only coupled for the necessary period with their carrying shafts.

In the majority of the transmission systems, the clutch is of the type operating by compressed air, the only exception being the Saurer-Arbon transmission system of the Swiss Railways, in which it works by oil under pressure.

As to the electrical transmission systems, the data received are unfortunately too scanty to permit us to come to any definite conclusions in this regard.

From the replies of the Rumanian and Danish Railways we may conclude that their rail cars have continuous current dynamos, operating at a voltage of 500 to 550.

They have two electric motors, each coupled to one driving axle. Regulation is effected by dynamo shunt control.

Number of passenger seats and classes.

This question being connected with the question of the maximum number of trailer cars which a rail motor-car can haul, we must study the latter first.

Table 5 shows us the corresponding figures.

We see that it is only on the Dutch Railways that the rail motor cars operate without trailers.

The reason is obvious, since these rail cars have the weakest motors in relation to the weight of the cars.

It is only in exceptional cases that the Dutch rail cars run with a van coupled between two motor-cars.

We see that the other rail cars can haul one, two or three trailers. In particular, 62 of these rail cars permit of two trailers (Danish, Rumanian, Swiss and Yugoslav Railways), 10 rail cars (9 petrol), three trailers (Rumanian Railways [petrol] and Swiss [Diesel]), and 7 rail cars, one trailer only.

It will be seen that of a total number of 79 rail cars studied, 62 (or 78 %) can haul two trailer cars; only a relatively small number (17 rail cars or 11 to 12 %) can haul one or three trailers.

But from the replies concerning the organisation of the rail car services, which we shall have to discuss further on, one can see that this maximum tractive power is not utilised in the majority of cases, since most of the rail cars run alone or only haul one trailer.

One may enunciate the conclusion that *the majority of modern rail motor-cars can haul two trailer cars, but in service actually haul one trailer only.*

The total weight of the trains, which corresponds to the maximum tractive force of the rail cars, varies between a minimum of 33.5 t. (33 Engl. tons) for the light petrol rail cars of the Danish Railways and a maximum of 83 t.(81.7 English tons) for the Danish rail cars.

The 133-t. (131 Engl. tons) Swiss rail car, with Diesel engine of 250 H.P., is only an exception to this rule.

It may be said that *the majority of the trains with rail motor-cars have a total weight of only 40 to 50 t. (39.4 to 49.2 Engl. tons).*

The total number of passenger seats in the train varies with the number of cars hauled. We see the minimum number corresponding to 78 (or 87) seats on the Finnish Railways, to the maximum of 188 seats for the Rumanian Railways in their petrol rail cars, and 230 seats in the exceptionally heavy train of the Swiss Railways. *The average figure is between 100 and 150 seats.*

We have already seen, however, that these figures are only attained in exceptional cases.

As to the passenger classes, we see that the majority of the rail cars and their trailers have only one class, the third.

The only railways which use rail cars and trailers of two classes are the Netherlands and the Yugoslav Railways.

The comparison of these data with those of 1909 shows us that at that time the difference between the classes used on rail car trains was very great; in fact, the majority of the rail cars comprised all three passenger classes. We thus see that practice has shown the disadvantage of such a system, and the necessity of only using the 3rd class in rail motor-cars and trailers.

TABLE

Maximum number of

RAILWAY.	Number of cars.	Number of seats in rail motor-car.	Total weight of rail motor-car (metric tons).
1. English, steam	55	...	31 2-35
	2		20.5-31.4
2. Danish, petrol	40	24-50-33-33	13.9-23.8-17.0-18.5
Diesel	6	60	45
3. Dutch, petrol.	13	85	40.4-40 2
Diesel	8	67	22
4. Rumanian, petrol	12	42	18.9-19 9
	9	36	21.8
5. Italian, petrol	2	70	28
Diesel	2	46	21
6. Finnish, petrol	2	42	23.7
Diesel	1	62	38.2
7. Swiss, petrol.	2	48	26.2
Diesel	1	50	63.0
8. Yugoslav, petrol	2	52	16.7

Remark. — (1) Except a van between 2 rail motor-cars; (2) 3rd c'ass; (3) 2nd class; (4) 3 with double heading;

Buffers and couplings.

It is obvious that the types used for these parts depend entirely on the construction of the trailer car used.

To haul cars of a standard railway type, the rail cars must have buffers and couplings of the railway pattern. Where special trailers are used, the buffers and couplings must also be of special type.

This is a great inconvenience, on the one hand, from the point of view of service organisation, but on the other hand the special trailer cars are much lighter trailers and passengers.

Trailers :				Total weight of train Q in metric tons.	Total number of seats.
Maximum number.	Weight in metric tons.	Number of seats.	Class.		
...	..	. .	. .	...	...
2	9.8	40-50-58-50	3rd	33.5-43.4-36.6-38 1	104-150 149-133
2	19.0	64		83	188
0 (1)			2nd and 3rd	...	. .
0	...	...	3rd		
2 (4)	11	50	3 (5)	42	142
3	11	50	3	54	186
1	16	50	3rd 3rd	44	120
1	12 (2)	45	3	36 (39) (2)	87 (78) (2)
1	15 (3)	36	3	50 (53) (3)	107 (98) (3)
2	13.5	50	3	53	148
3	23.0	60	3	70-63-133	230
2	11.3	48	2nd and 3rd	39.3	148

(5) Occasionally 2 in tow.

(11 t. [10.8 Engl. tons] as against 16.5 t. [16.2 Engl. tons], for example), and the considerable average speeds of the trains can be maintained in this case with motors of lower power — in other words, more economically.

The data of table 6 show us that 112 cars are provided with buffers and couplings of a standard railway type, and that there are only 45 cars (of the Rumanian and Yugoslav Railways and the Danish petrol cars) which have fittings of a special type. From this it is clear that the maojrity of the rail motor-cars have couplings of a standard type and can thus haul ordinary carriages and vans.

The data of 1909 show us that at that time the rail cars, for the most part of the steam type, had only standard couplings, except for the Daimler system only, which had no coupling, because the car always ran alone.

From this we see that in the period of twenty years the use of special trailers has slightly developed.

As a conclusion we can say *that for the modern rail cars the use of railway type couplings is standard, but the use of special couplings is nevertheless making progress.*

Braking methods.

The table of replies to the questionnaire (Appendix II) gives us information on the subject of the methods of braking used on rail motor-cars and their trailers.

We observe that everywhere the cars have two braking systems: *a*) hand brakes (screw or lever), and *b*) automatic air brakes, of an ordinary railway type.

Such an equipment of modern rail motor-cars with duplicate braking arrangements can be regarded as standard.

Heating and lighting.

The same table 6 shows us that the system of heating universally employed for rail cars with internal combustion engines is that of circulation of the hot water coming from the engine cooling system. The three petrol rail cars of the Swiss Railways alone have heating by means of the exhaust gases from the motor.

As to the heating of the trailers, which is naturally much more difficult to carry out in a practical manner, we see that the majority of administrations have in these trailers the same heating system as in the rail motor-cars themselves, i.e. by means of the cooling water.

The Finnish and the Yugoslav Railways have the trailers heated by small coal stoves.

As to the lighting system, we see everywhere the exclusive use of electric lighting.

We see that there must be considered as standard for modern rail motor-cars and their trailers heating by cooling water from the engine, and electric lighting.

The English steam cars naturally are heated by steam from the boiler, at reduced pressure, but electric lighting is also fitted.

Minimum radius of curves.

The modern rail motor-car runs on the same lines, main or secondary, as the steam locomotive, and must therefore be capable of negotiating the same minimum radii, for example those of 120 to 150 m. (6 to 7 1/2 chains).

Table 6 shows us that the majority of rail motor-cars can negotiate curves of much smaller minimum radius, nearly always below 100 m. (5 chains).

We do not find larger minimum radii than on the Danish Railways (150 m. [7 1/2 chains]) and the Finnish Railways (270 m. [13 1/2 chains]).

This last figure is, however, so high as to give rise to the suspicion of an error.

Number of driver's compartments.

It is obvious that if the rail car has a driver's compartment at each end, it need not be turned at the terminal stations, or run with the trailer cars in front; thus it avoids all the well-known resultant drawbacks.

The same table 6 shows us that the majority of the cars have two compartments, fitted with all the necessary equip-

TABLE 6.

Technical data for rail motor-cars

Railway.	Number of rail cars.	Buffers and couplings.	Brakes.	Heating.	Lighting.	Minimum radius of curves (in metres).	Number of engineer's compartments.
1. English. . . .	57	Standard.	1, hand. 2, air.	Steam, cooling water.	Electric.	...	2
2. Danish	46	22-special. 24-standard.	1, lever. 2, Knorr, compressed air.	Cooling water.	Electric.	150	1 (38 rail cars). 2 (8 rail cars)
3. Dutch	21	Standard.	1, screw. 2, Westinghouse.	Ditto.	Electric.	I and II — 60, III — 90.	2
4. Rumanian . . .	21	Special.	1, hand. 2, air. 2, air « Böcker ». 3, electric.	Ditto.	Electric.	80	1
5. Italian	4	Standard.	1, screw. 2, Westinghouse.	Ditto.	...	60	2
6. Finnish. . . .	3	Standard.	1, screw. 2, Westinghouse.	Ditto.	Electric.	270 (?)	2
7. Swiss . . .	3	Standard.	1, screw. 2, Westinghouse.	Exhaust gases, cooling water.	Electric.	...	2
8. Yugoslav . . .	2	Special.	1, hand. 2, compressed air.	Cooling water.	Electric.	90	2

ment required by the driver to drive the car.

The single driver's compartment arrangement exists on the following rail motor-cars :

1. The light petrol cars (those of the types Ma, Me and Mf, to the number of 38) of the Danish Railways;

2. The 21 petrol cars of the Rumanian Railways.

Thus of the 157 rail motor-cars in use, 98 (or 62 %) have a compartment at each end, and only 59 (or 38 %) have a single compartment only.

From the service results of the rail motor-cars on the various railways, we shall see later the influence of this detail on the organisation of the service.

II. — Organisation of the service. Method of use.

According to the principal data of the table in Appendix II concerning rail motor-cars, also of the various tables of the first part of this report, we can now examine the organisation of the service and the method of use of the rail motor-cars utilised by the various railway administrations.

The Danish Railways have the largest number of rail motor-cars in operation; they possess 46 such cars, of which 40 are petrol cars of the two or three-axle type, of four different models varying in weight from 13.9 to 23.8 t. (13.7 to 23.4 Engl. tons) the petrol motors are of 100 H.P., with mechanical transmission.

The other 6 rail motor-cars are cars of 45 t. (44.3 Engl. tons) of the 4-axle type, with Diesel engines of 180 H.P., having electrical transmission.

Figures 1 to 5 show the diagrams of the Danish cars.

The rail car trains of the Danish Railways are usually formed of two rail motor-cars coupled end to end, i.e. by their rear portions, with one or two trailer cars between the two motor-cars.

The maximum nūmber of seats in the train may be from 104 to 188.

In the event of a rush of passengers, ordinary steam trains are used.

All the rail motor-cars and trailer cars have only one class (3rd).

All the petrol cars have one driver's compartment only, but owing to the coupling of the cars in the train end to end, the rail motor-cars always run with the driver's compartment leading. In this case the trains have special signals for the synchronous working of the engines and brakes. The motors of the two rail cars only work together in case of maximum load.

Each rail motor-car has its driver and its guard. There is always a passage between the motor-cars and the trailer cars.

The rail motor-car trains run on many lines, the shortest of which is the Copenhagen-Hellemp line (4.6 km. [2.85 miles]) on which these trains run 286 km. (177.8 miles) per day, and the longest the Maathus - Frederikshavn, 224.1 km. (139.3 miles), with a daily kilometrage of 367.1 km. (228.1 miles).

This line has two rail cars in service.

The longest daily kilometrage, 1 132 km. (704 miles) per day, is effected on the lines :

1. Strib-Nyborg, 83.2 km. (51.7 miles); and Odense-Assens, 44.3 km. (27.5 miles), on which there run six petrol cars, and

2. Naestved - Frederikssund, 83.8 km. (53.8 miles) and Copenhagen-Frederikssund, 41.8 km. (26.0 miles), on which there work three Diesel cars with a total kilometrage of 300 km. (186.4 miles) a day.

The whole of the rail motor-cars of the

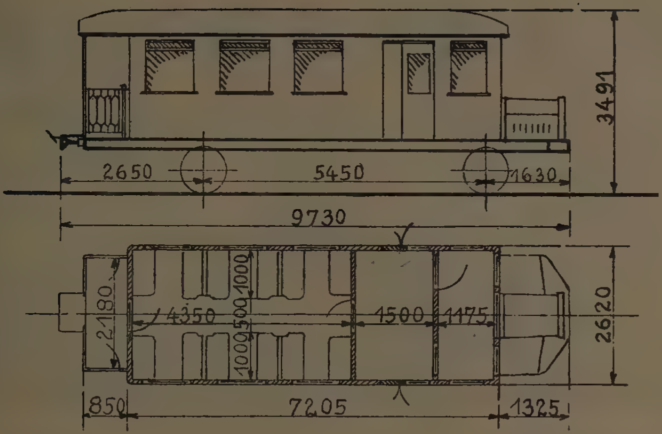

Fig. 1. — Danish Railways. — Rail motor-car with petrol engine, type Mc.

24 seats, 3rd class. Tare 10,8 tons (approx.).

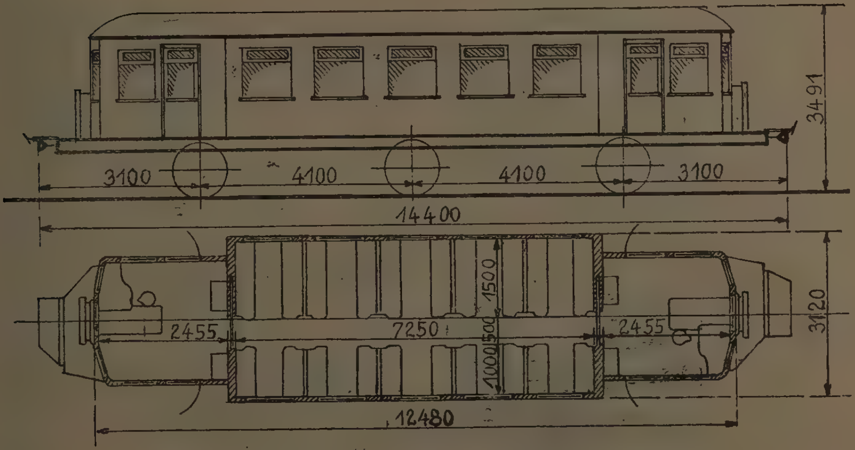

Fig. 2. — Danish Railways. — Rail motor-car with two petrol engines, type Mc.

50 seats, 3rd class. Tare 19 tons (approx.).

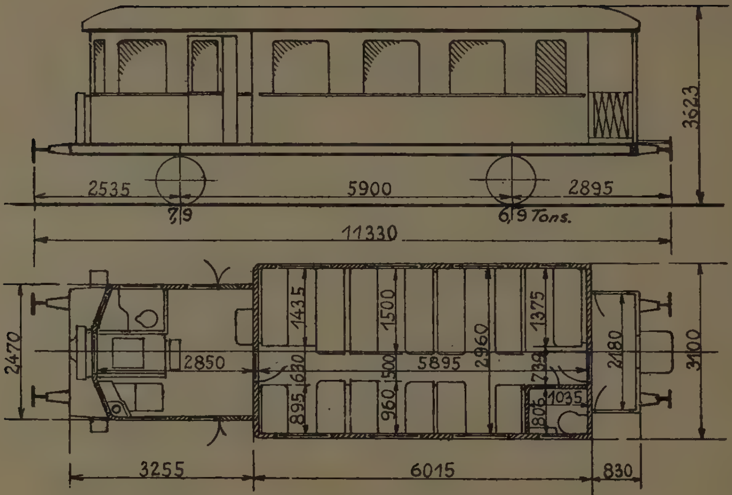

Fig. 3. — Danish Railways. — Rail motor-car, petrol drive, type Mf.

33 seats, 3rd class. Tare 14.6 tons (approx.).

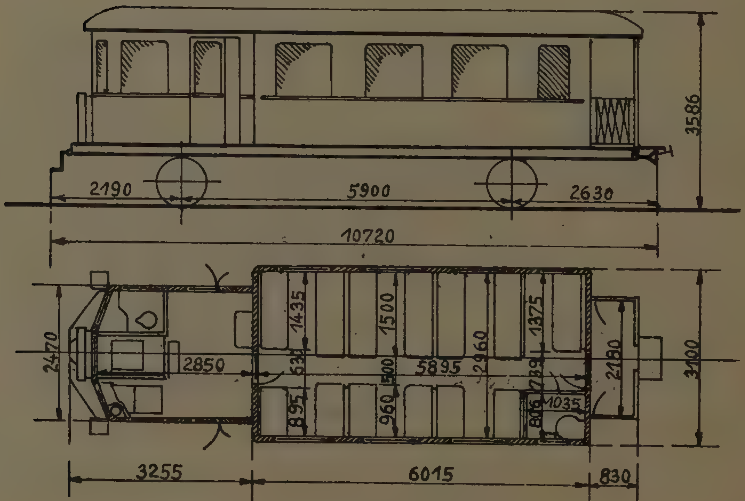

Fig. 4. — Danish Railways. — Rail motor-car, petrol drive, type Me.

33 seats, 3rd class. Tare 13.3 tons (approx.).

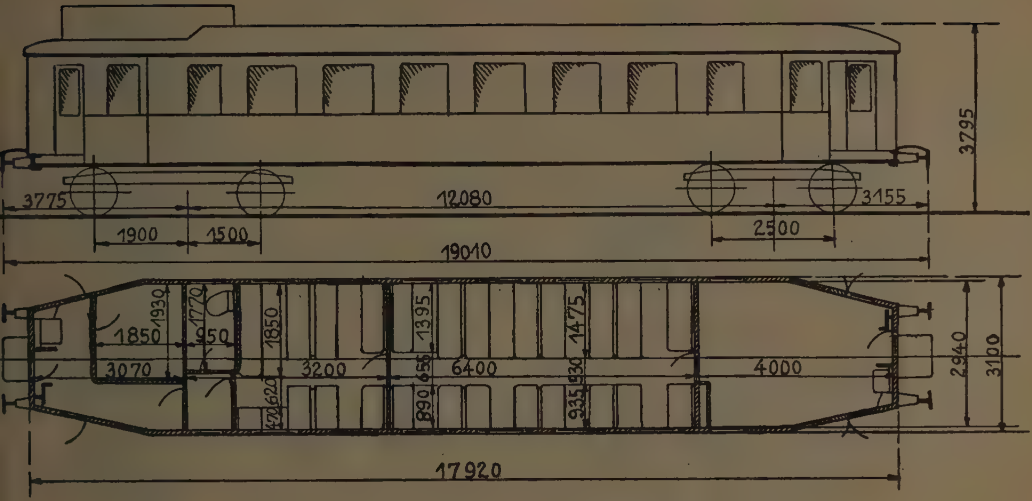

Fig. 5. — Danish Railways. — Rail motor-car, with Diesel engine of 180 H. P., type Mr. 60 seats, 3rd class. Tare 41.3 tons (approx.).

Danish Railways together do up to 7 330 km. (4 555 miles) per day.

The lines served by rail motor-cars are not always of local or secondary interest, but main lines as well, on which the rail car trains serve to augment the frequency of the train service with a view to meeting the competition of trams and buses on parallel routes. On these main lines, the rail car trains ensure the local communications and suburban services.

The Danish rail cars have been deemed capable of ensuring regular service on lines with a maximum gradient of 1 in 100, 8 km. (5 miles) long, at an approximate speed of 20 km. (12.4 miles) an hour.

The maximum speed of the motor-car trains may reach 70 to 75 km. (43.5 to 46.6 miles) per hour. It is interesting to note that the Danish rail car trains precede and follow fast steam trains, i.e. they carry out with success the same service as the ordinary local trains.

The rail car trains are served by the same staff as works the ordinary railways, also by a specialist staff, i.e. drivers specialising in petrol and Diesel engines, and specialist electricians.

The administration makes this comment, that the specialist staff must be fairly well trained to give satisfactory service on rail motor-cars.

The rail motor-car service is organised in such a way that all the principal stations have one or two cars in reserve. The fuelling of the cars is effected every 200-250 km. (124 to 155 miles) as regards petrol, and every 350-400 km. (217.4 to 248.6 miles) as regards oil. Water, of which very little is used, is only taken when required.

The rail motor-cars are all housed and

maintained in the ordinary locomotive depots.

The administration of the Danish Railways is satisfied with the service of its rail cars; it has no difficulty in maintaining a regular service.

The Danish administration has now under consideration the extended use of rail motor-cars on its lines, and has in preparation four rail motor-cars of the two-engine type and with electrical transmission.

English Railways.

The London & North Eastern Railway has a very large number of rail motor-cars in service. Unfortunately, in the absence of details, it is impossible for us to give a complete description of the service of these cars.

Dutch Railways.

The Netherlands Railways have 21 rail motor-cars in service, 13 of which are fairly heavy vehicles, of 40 t. (39.4 Engl. tons), 4-axles, with petrol motors.

Of these 13 cars, three, with seating for 2nd and 3rd classes, have only one engine; the others have two engines, one at each end of the car.

All these motors are made by the firm of N.A.G., Berlin, and are of 70 H.P.

Eight others are of the 2-axle type, with a 75-H. P. Diesel engine, made by the M.A.N. firm; they have only 3rd class seats.

All the rail motor-cars have mechanical transmission, both the petrol cars of the A.E.G., Berlin, and the Diesel engine cars of the D.G.G. concern, Hanover.

Figure 6 shows a Dutch rail motor-car with two petrol engines.

All the cars have two driver's cabins, and run :

1. Motor-car alone;
2. Two motor-cars coupled;
3. One or two motor-cars, hauling a van.

The rail motor-cars never haul passenger trailers, since, as we have already seen above, the Netherlands Railways' rail cars have the lowest powered motors in relation to the weight.

There is no intercommunication between the coupled motor-cars, but the trains have always only a single driver and a single guard.

The motor-car trains of the Netherlands Railways run on the main as well as on the branch lines, in correspondence with the ordinary steam trains. The Administration of the Netherlands Railways, in the organisation of the service of its rail motor-cars, had in view the transport of passengers at high speed, capable of meeting the competition of modern motor-buses.

The petrol rail cars do a total of 1 719 km. (669 miles) per day, and the Diesel engine cars 876 km. (544 miles). The longest line is that from Zwolle to Enschede, on which the rail cars do 354 km. (220 miles) per day. The average annual running of the petrol cars totals 50 000 km. (31 070 miles) approximately, and that of the Diesel cars attains some 37 500 km. (23 300 miles).

The reserve of fuel in the petrol tanks allows of 470 to 580 km.(292 to 360 miles) being run, and that in the oil tanks of the Diesel engines 675 km. (419 miles).

The Administration of the Netherlands Railways has had no difficulty in maintaining regular service with its rail motor-cars, except in a few cases at the commencement of the operation of the Diesel engined cars, because of the lack of experience of the specialist crews.

The Administration is now engaged in preparing or trying seven 4-axle cars, 2nd and 3rd class, with two petrol engines, with the mechanical transmission system

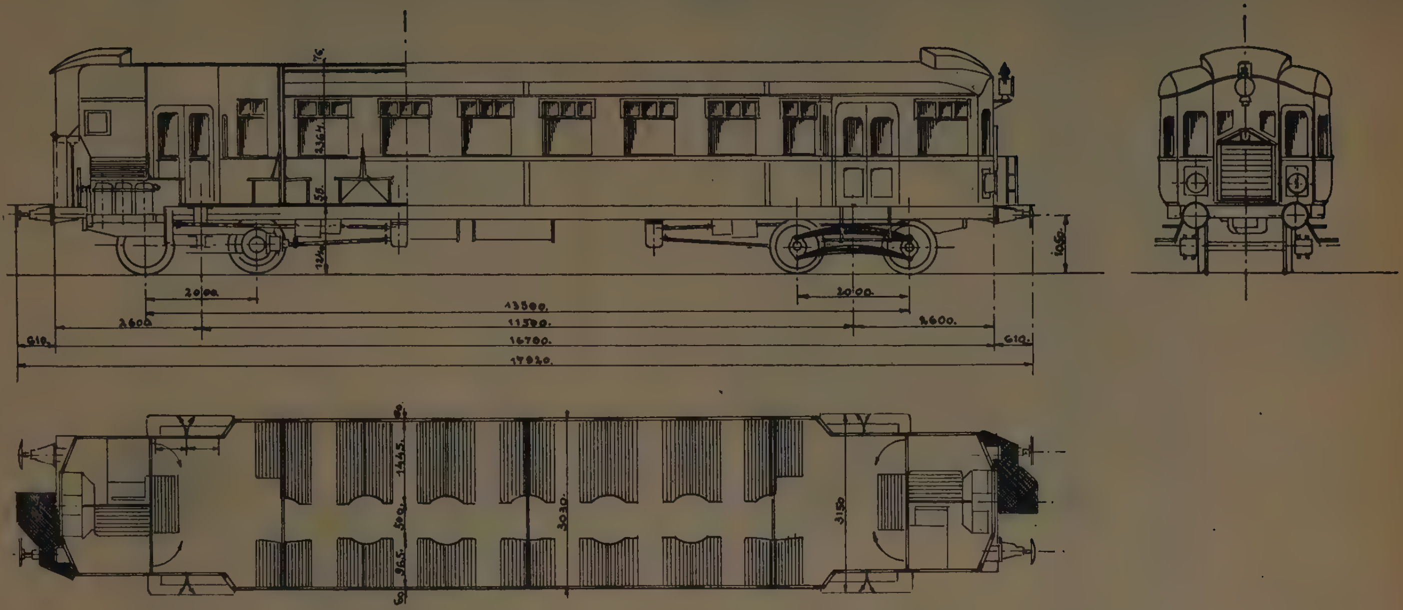

Fig. 6. — Netherlands Railways. — Rail motor-car with two petrol motors.

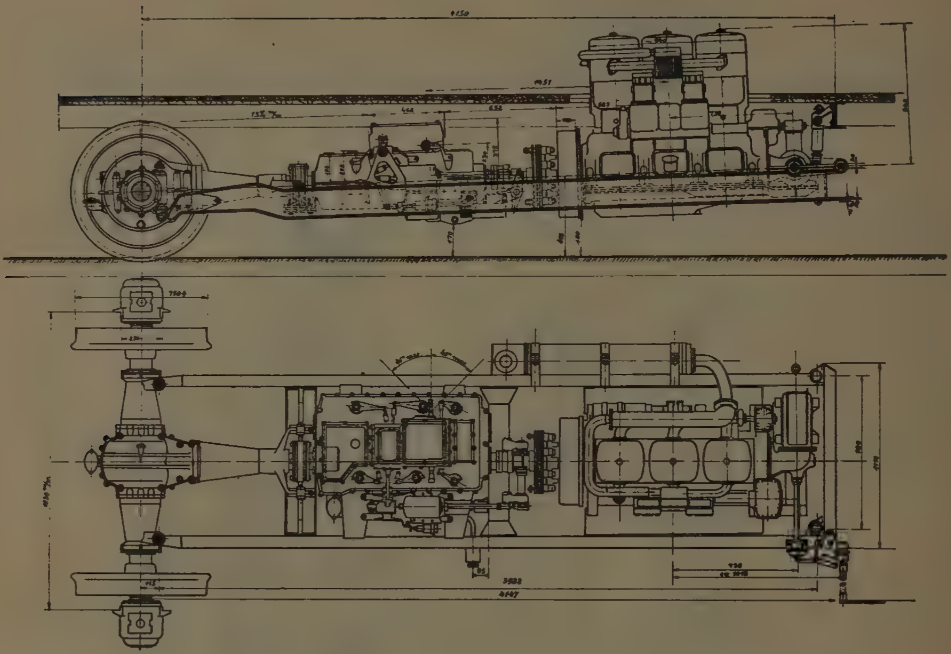

Fig. 7. — Netherlands Railways. — Motor chassis of the Diesel engined rail motor-car (M. A. N. engine).

of the A.E.G., Berlin, and six lighter 2-axle cars with a single petrol engine and the mechanical transmission system of the D.G.G., Hanover.

All the Dutch rail cars are kept housed in special depots.

Figure 7 shows the special chassis of the Diesel engined rail motor-car, on the system of the M.A.N., Augsburg, and figures 8 and 9 show the diagrams of the change-speed gearing of the rail motor-cars with one and two engines.

Rumanian Railways.

The Rumanian Railways have 21 rail motor-cars in operation. All the cars are petrol driven, with electrical transmission. Five of them, of the Westinghouse firm, Havre, have petrol engines of 60 H.P. and are of the 4-cylinder type; seven others have 4-cylinder engines made by De Dion, Paris, of 70 H.P., and nine have 6-cylinder, 90-H. P. engines made by the same firm of Westinghouse, Havre.

The Rumanian Railway Administration has been using rail motor-cars since 1903, and has much experience in this connection.

All the Rumanian cars have only a single driver's compartment, and the Administration has therefore always to organise the service in such a way as to

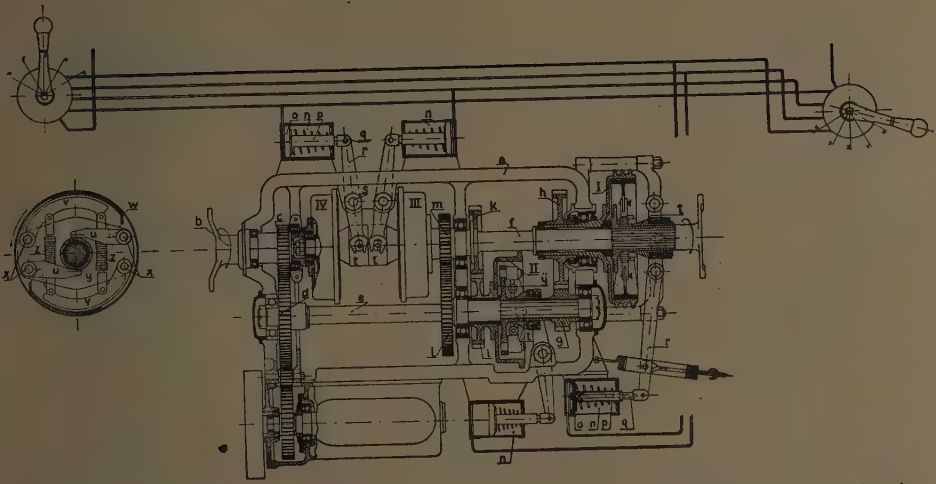

Fig. 8. — Netherlands Railways. — Diagram of change-speed gear box of rail motor-car with one petrol engine.

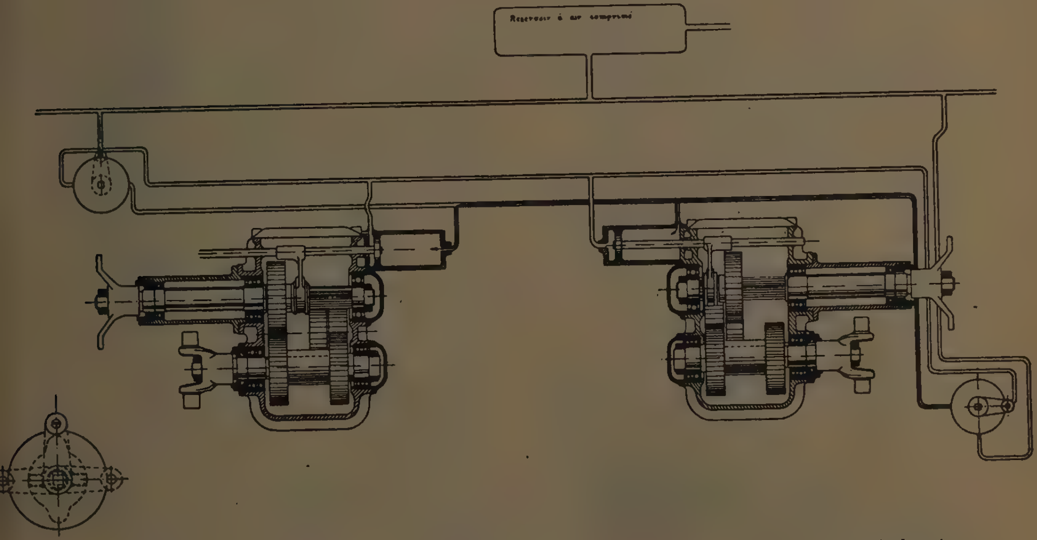

Fig. 9. — Netherlands Railways. — Diagram of change-speed gear box of rail motor-car with two petrol motors.

avoid the running of trains with the trailers in front.

The Rumanian rail cars are capable of hauling up to 3 trailer cars of a special light type with two axles, of 11 t. (10.8 Engl. tons), with 50 seats, and with central buffers and couplings.

The maximum numbers of seats for passengers in the Rumanian rail car trains, and their maximum speed, are as follows :

1. With one trailer only (fast trains) 24 2nd class and 50 3rd class seats, i. e. a total number of 74 seats, with a maximum speed of 60 km. (37.3 miles) per hour.

2. With two trailers (omnibus trains, running on branch lines with light traffic), in which the total number of seats, 2nd and 3rd, is 142, the maximum speed is 50 km. (31 miles) per hour.

3. With three trailers (omnibus trains on heavy traffic lines), in two variants :

a) with two rail motor-cars of 60 or 70 H.P. coupled (double traction), the total number of 2nd and 3rd class seats is 234, and the maximum speed 50 km. (31 miles) per hour, and

b) with a single rail motor-car of 90 H.P., having a total number of 186 seats, and a maximum speed of 50 km. (31 miles) per hour.

The trains have intercommunication between the rail motor-cars and trailers — by direct gangways in the trains with 90-H. P. cars, and indirectly (by footboards) for the others.

Rail motor-car trains are never used for goods transport, because the special couplings do not allow of the ordinary goods wagons being coupled to them.

Each train is worked, along with the driver, by a driver's assistant. The train service is effected by one or two train men and a guard.

The special staff is trained very carefully : the drivers have all worked beforehand in the rail car erection and repair shops; afterwards they work as driver's assistants, and can only become rail motor-car drivers after a special and very thorough examination.

Only certificated steam locomotive drivers can be candidates.

The most difficult Rumanian lines served by the rail cars are those of Arad-Brad, 167 km. (103.8 miles), and Arad-Oradca-Mage, 240 km. (149 miles), on which the maximum gradients are 8 per thousand (1 in 125) and 5 km. (3.1 miles) long.

The rail motor-cars are in operation :

1. on secondary light traffic lines, on which circulate a total of two trains with rail motor-cars; the total traffic is 64 tr.-km. (39.8 train-miles) with 2 034 passenger-km. (1 264 passenger-miles) per day; 2. secondary lines, but with much heavier traffic, on which there are employed 8 trains, with 1 064 tr.-km. (661 train-miles) and 44 253 passenger-km. (27 498 passenger-miles) per day; and 3. main lines, in co-operation with steam trains, 28 motor-car trains running per day with the considerable number of 2 572 tr.-km. (1 598 train-miles) and 155 788 passenger-km. (96 800 passenger-miles), per day. We see, thus, that the use of rail motor-cars on the Rumanian Railway System is very important.

The total annual distance travelled by the Rumanian rail motor-cars is :

Cars of 60 to 70 H.P., up to 40 000 km. (24 900 miles).

Cars of 90 H.P., up to 50 000 km. (31 000 miles).

The Administration of the Rumanian Railways has in hand the organisation of the use of larger and more powerful rail cars than those so far used.

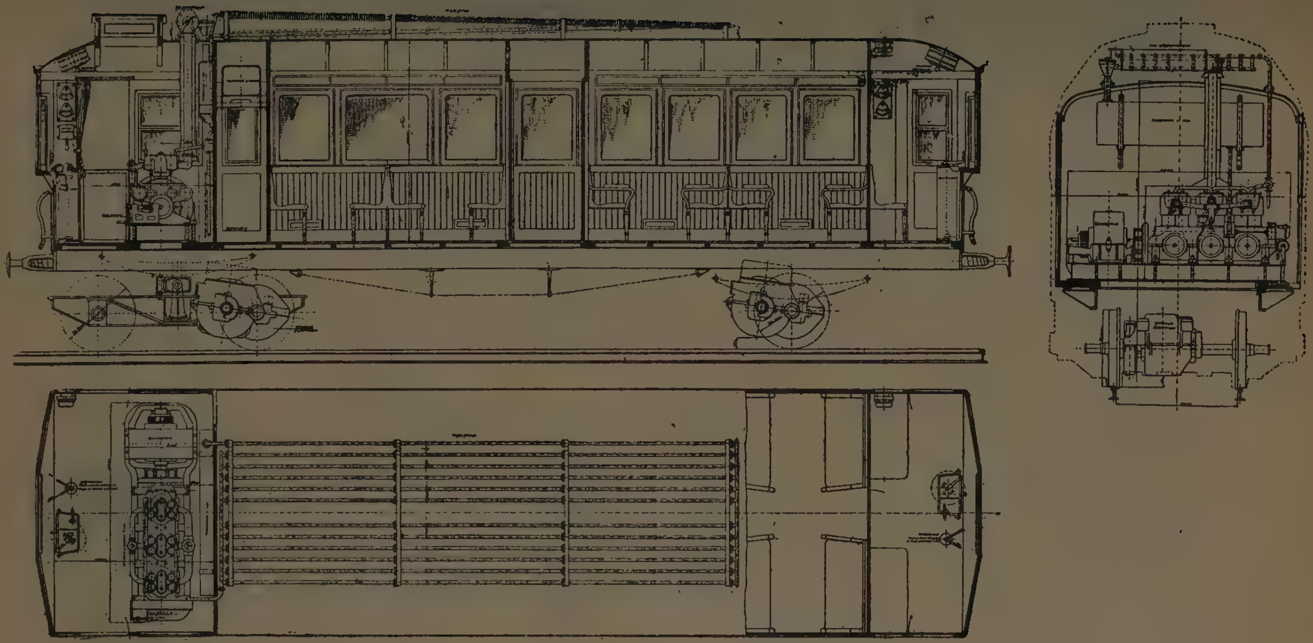

Fig. 10. — Rumanian Railways. — Rail motor-car, petrol driven, electric transmission.

These new rail motor-cars are 4-axle cars with Diesel engines of 120 to 200 H.P., which in the opinion of the Administration will be more economical in service than the petrol cars, and will permit the economic yield of its light-traffic branch lines to be increased, so that the competition of motor-buses on the roads may be met.

The Rumanian rail motor-cars are all housed in special depots, and this, according to the Administration, for the following reasons :

1. The great inflammability of the petrol spirit; and

2. The absence of the standard buffer and coupling gear. To diminish the risk of collisions with ordinary wagons and carriages, the rail motor-cars and their trailers are painted bright red and bright yellow.

The tanks of the rail motor-cars are sufficient for the following runs without refilling :

60 H.P. cars, 200 km. (124 miles).
70 H.P. cars, 250 km. (155 miles).
90 H.P. cars, 350 km. (217 miles).

The Administration of the Rumanian Railways remarks that it experiences no difficulty in maintaining a regular service, and that the Rumanian public much appreciates the rail motor-cars because of their cleanliness and of the frequency and speed of the service compared with steam trains on branch lines.

Figure 10 shows the Rumanian 90-H. P. rail car.

Finnish Railways.

The Finnish Railways have at present only 3 rail motor-cars in service, of which:

1. Two are cars of 23.8 t. (23.4 Engl. tons), petrol driven, with mechanical transmission, 2 axles, with a 75-H. P. motor by the A.E.G., Berlin, and

2. One is a car of 38.2 t. (37.6 Engl. tons) weight, with 4 axles, Diesel Engine of 90 H.P., 6-cylinder type, by the Swedish firm « Diesel-Electr. Vesteras A/B ».

The cars themselves were made in the State Railway Workshops.

The Finnish rail motor-cars have two driver's cabins, and run either alone or coupled to one trailer, a car of the ordinary railway type, 12 t. (11.8 Engl. tons) in weight for the 3rd class cars with 45 seats, and 15 t. (14.8 Engl. tons) for the 2nd class cars with 36 seats.

The maximum number of seats in a rail car train is :

1. For petrol motor-cars 87 seats (78 if the trailer is a 2nd class car);

2. For Diesel engined cars 107 (or 98) seats.

The Finnish rail car trains have intercommunication between the motor-car and trailer, and are always staffed by a driver and guard.

The rail motor-cars run exclusively on branch lines, in connection with the steam trains on the main lines.

The most difficult line served by the petrol cars is that of Kouvola-Kymintehtas, which is 5.6 km. (3.5 miles) long and has a maximum gradient of 20 $^{00}/_{00}$ (1 in 50) and 12 $^{00}/_{00}$ (1 in 83) on a length of 8.75 km. (5.44 miles). The corresponding speed is 15 to 26 km. (9.3 to 16.8 miles) per hour.

The Finnish rail cars ran in 1928 :

1. Petrol car alone, 37 546 tr.-km. (23 300 train-miles); with its trailer 2 900 tr.-km. (1 800 train-miles); total 40 446 tr.-km. (25 100 train-miles) per annum.

2. Diesel engined car, alone, 42 514 tr.-km. (26 417 train-miles); with its trailer 16 062 tr.-km. (9 980 train-miles); total 58 576 tr.-km. (36 397 train-miles).

In the case of a rush of passengers, recourse is had to ordinary steam trains.

The Finnish State Railway Administration is satisfied with the work done by its rail motor-cars, and is about to obtain two more for these branch lines.

It is not proposed to use the rail cars on the main lines.

Italian Railways.

As we have already seen, the Italian Railways have 4 rail motor-cars, two petrol driven with mechanical transmission, and two Diesel engine driven with electric transmission. Unfortunately, in the data received, we do not find either the seating accomodation per car nor the power of the engines, and because of this we cannot compare them with the cars of other railways. Usually these rail cars run alone, without trailers. In exceptional cases a 12-t.(11.8 Engl. tons) trailer for 50 third class passengers is coupled on. The rail cars have two driver's compartments, and do not have to be turned at the terminal stations. The car is staffed by a driver and a guard; should a trailer be attached, this has its guard, because there is no gangway between the motor-car and the trailer.

The cars ensure the local service on the line Leghorn-Colle Salvetti, 17 km. (10.5 miles) long. The run takes 29 minutes.

The heaviest gradient is 8 $^{00}/_{00}$ (1 in 125), on a length of 0.6 km. (0.37 mile). Each train traverses this line twice a day, i.e. a total trip of 34 km. (21.1 miles) only.

With one charge of fuel and water, the car is capable of running 100 km. (62 miles); it can climb a gradient of 25 $^{00}/_{00}$ (1 in 40) on a length of 7 km. (4.35 miles) at a speed of 30 km. (18.6 miles) per hour.

In rush hours, a trailer is attached for 50 passengers, and if that is not sufficient, a steam hauled train is used.

The Italian Railway Administration is satisfied with the work of these cars, and has the intention of replacing on this line all other means of transport by Diesel engined rail motor-cars.

The administration remarks that these rail cars are not so flexible in service as steam locomotives, that it is difficult with them to make up delays, and that they are accommodated in the same depots as the locomotives.

As to the use of these cars on main lines, the administration is not contemplating this.

Swiss Railways.

The Swiss Federal Railways have only 3 rail motor-cars in service, two of which are cars of a weight of 26.2 t. (25.8 Engl. tons) total, with 2-axles and 48 third class seats, with petrol engines of 100 to 120 H.P., by the firm of AD. Adolf Saurer, Arbon, and one heavy car of 63 t.(62 Engl. tons) total weight, with 4 axles and 50 third class seats, with an eight-cylinder V. Diesel engine of 250 H.P., by Sulzer Brothers, Winterthur, Switzerland.

The electrical portion was made by the Brown-Boveri Co., Baden.

All the cars have two driver's compartments, and run in either direction without being turned. The rail cars usually run alone, but in case of need they can haul one or two carriages or goods wagons of the ordinary railway type. All the motor-car trains have Westinghouse air brakes, except those hauling goods trains, which are only fitted with ordinary screw brakes.

In the case of an exceptional rush of passengers, also in case of damage to the rail motor-cars, they are replaced by ordinary steam trains.

The trains are served by a driver and a guard.

The Swiss rail cars only serve branch lines which are not electrified as are all

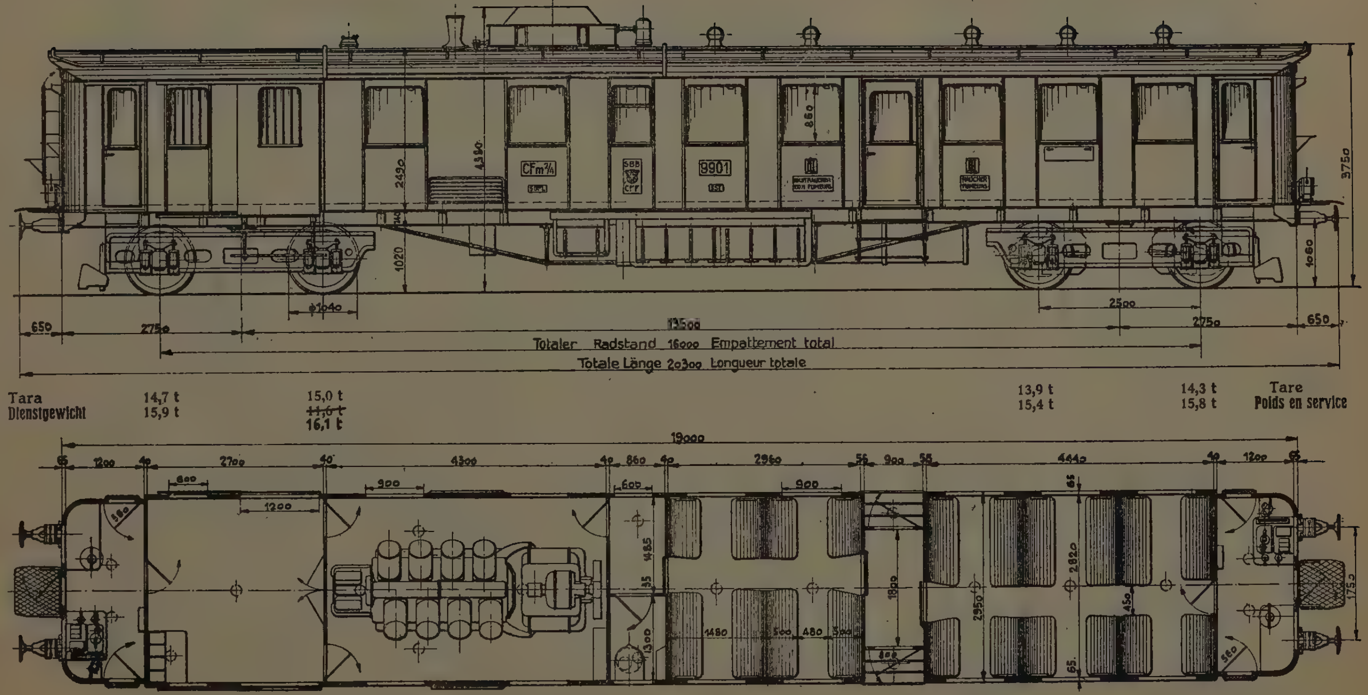

Fig. 11. — Swiss Federal Railways. — Rail motor-car with Diesel engine of 250 H. P.

Number of seats, 3rd class : 50.
Luggage compartment : 75.3 sq. feet; load : 1 $1/2$ tons.
Maximum speed : 46.6 miles per hour.

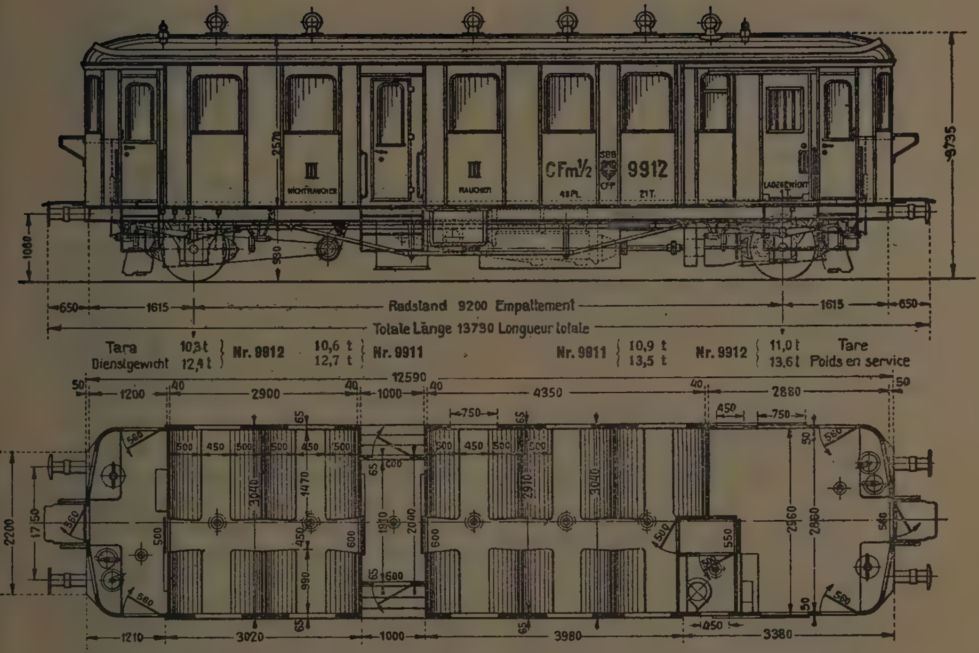

Fig. 12. — Swiss Federal Railways. — Petrol driven rail motor-car of 100 H. P.

Number of seats, 3rd class : 48.
Luggage compartment : 43 sq. feet; load : 1 ton.
Maximum speed : 31 miles per hour.

the main lines of the Swiss Railways, and they thus replace with much success the local steam trains.

The most difficult lines are the following :

1. Uznach-Linthal and return, 39.5 km. (24.5 miles) on which the petrol cars are run. This line has maximum gradients of 20 $^{00}/_{00}$ (1 in 50), on a length of 1.6 km. (1 mile) (Diesbach-Kuti-Linthal);

2. Wettingen-Turgi-Brugg, with a total length of 10 km. (6.2 miles) and with gradients up to 12 $^{00}/_{00}$ (1 in 83).

The daily run of the rail motor-cars is as much as 185 km. (115 miles). The tanks are sufficient for a run, without refilling, of 300 km. (186.4 miles) for the petrol cars, and 350 km. (248 miles) for the Diesel cars.

The cars are housed in the steam locomotive sheds.

The Administration of the Swiss Federal Railways informs us that it has no difficulty in maintaining its rail motor-cars in regular service.

There were some difficulties as to the

storage of the rail motor-cars, because of their construction, more delicate and complicated than that of the steam locomotives, and also because the small number of rail motor-cars did not permit of having an adequate supply of spare parts always available.

The Swiss Federal Railways have now in construction the following cars :

One Diesel engined car of 420 H.P., with electrical transmission, and one Diesel car of 300 H.P., but with mechanical transmission.

Figures 11 and 12 represent the Swiss rail motor-cars.

Yugoslav Railways.

The Yugoslav Railways have only two petrol rail motor-cars, with two axles, on test. The total weight of these cars is 16.7 t. (16.4 Engl. tons). The number of seats is 52, i. e. 12 second and 40 third class.

The rail cars work two lines :

1. Subotica-Horgos, 27.5 km. (17.1 miles) long, on which the rail car runs always alone, and

2. Subotica-Tchantavire, 23 km. (14.3 miles) long, on which it hauls a trailer.

The Yugoslav rail cars have only been a very short time in service; the Administration has as yet not much data with regard to the results of their operation. Some data of an economic nature are given in part III of this Report.

III. — Economic results of the operation of rail motor-cars.

Table 7 shows us the economic results of operation of rail motor-cars on the European lines, also the cost of the cars.

The operating costs do not include either sinking fund charges on the cars nor the interest on the value of the cars and trailers.

As it appears from this table, the costs of the cars are very different, and vary from 8 500 to 14 500 American dollars for the Rumanian, Italian, Finnish, Danish and Yugoslav petrol cars, totalling 67 cars at a price of $0.55 to 0.82 per kgr. ($0.25 to 0.37 per lb.) of weight unloaded, to as much as $54 970 ($0.91 per kgr. [$0.41 per lb.]) for the Swiss rail motor-cars with 250-H. P. Diesel engines.

It is interesting to compare the costs of the rail motor-cars of various systems of which we possess data :

—	Transmission.	Number of cars.	Price in thousands of American dollars.
Petrol . . .	Mechanical. .	61	46 cars : 13-14.5; 15 cars : 18-26.
	Electrical . .	27	27 cars : 23-32.
Diesel . . .	Mechanical. .	8	8 cars : 19.
	Electrical . .	10	3 cars : 21.7-25.6; 6 cars : 32 ; 1 car : 54.9.

As will be seen, the petrol rail cars with mechanical transmission are the least costly; in fact, the cost of the majority — 46 cars or 75 % — is from §13 000 to 14 500, while the price of 15 cars only (25 %) is 18 600 to 26 000.

The Diesel rail motor-cars with mechanical transmission cost almost the same as the higher-priced petrol cars with mechanical transmission.

At the price of $23 200 to 32 000 the petrol rail cars with electrical transmission are already dearer than the mechanical transmission type, while the Diesel driven cars with electrical transmission of the least costly type cost approximately the same as the petrol cars with electrical transmission, but their maximum price is much higher : it is $32 000 for the six Danish cars with 180 H.P. motor, and $54 900 for one Swiss car, with an engine of 250 H.P.

As will be seen, it is the electrical transmission which greatly increases the cost of the rail motor-car, while it matters little from the point of view of cost whether the engine is of the petrol or Diesel type.

As to the cost of the special trailers, it will be seen that it is, for the petrol rail cars with mechanical transmission of the Rumanian and the Yugoslav Railways, $4 000 to 6 500; for a weight of 11 to 13 t. (10.8 to 12.8 Engl. tons) this comes to $0.36 to 0.578 per kgr. ($0.163 to 0.262 per lb.).

As a comparison, the cost of a simple 3rd class car, for 60 passengers, with 2 axles, weighing about 16 t. (15.7 Engl. tons), may serve for an example. This cost is about $6 500, or $0.41 per kgr. ($0.186 per lb.).

Passing to the comparison of the costs of operation of the rail motor-cars, we would remark that we have incomplete data with regard to these railways.

The figures quoted do not include sinking fund or capital charges, since we have not these data.

We see from this table that the operating costs are least for the Rumanian and Finnish railways; for light petrol rail cars they are $7.05 and 7.15 per 100 km. ($11.34 and 11.50 per 100 miles). These costs are also $5.13 per 100 km. ($8.25 per 100 miles) for the Finnish Diesel rail cars. All the other railways show much higher costs for their cars. Thus they are $11.86 to 12.43 per 100 km. ($19.08 to 20.00 per 100 miles) for the petrol rail cars of the Dutch and English Railways, $16.35 to 17.74 per 100 km. ($26.31 to 28.54 per 100 miles) for the petrol rail cars of the Yugoslav Railways.

The costs of the English steam rail cars amount to $13.5 per 100 km. ($21.72 per 100 miles) and finally the operating costs of the steam trains on the Rumanian local lines which run in parallel with the rail motor-cars amount to $10.08 per 100 km. ($16.22 per 100 miles).

CONCLUSIONS.

From the results of our study of the information we have received from the railway administrations indicated, we can now establish some definite conclusions with regard to the present position of the question before us — the use of modern rail motor-cars on railways.

There are two types of rail motor-car which can be considered today as standard :

1. *Light type.* — The rail motor-car of this type is provided with a petrol motor of power up to 100 H.P., speed 1 000 r.p.m., 6 cylinders. It is of the two-axle type, and is capable of running alone at a speed of 60-65 km. (37.3 to 40.4 miles) per hour. The car has mechanical transmission, i.e. by gearing, of a modified motor-car type (the gears are always in mesh, and the clutch is operated by compressed air). There are normally four speeds forward and one reverse. The car is provided with two driver's compartments, and can be driven from either end; it has approximately 50 seats for passen-

TAB
Economic results

RAILWAY.	CONSUMPTION				COSTS P				
	Fuel		Oil						
	per 100 km. Kgr.	Cost per kgr.	per 100 km. Kgr.	Cost per kgr.	Fuel.	Oil.	Lighting.	Water	Staf
English :		Coal.							
Steam	316.1 342.9	15/8 per t.	...	...	66.7	23.0	5:9	6.5	310
Petrol.	53.7	1 sh. per gallon.	...	...	...	...	...	...	...
(Sh. and d.)									
Danish :									
Petrol	40.0	...	...	...	11	1	...	...	...
Diesel	60.0	...	...	...	...	...	...	...	...
(Danish crowns.)									
Dutch :									
Petrol I	117.0	...	...	...	7.60	0.45	...	...	6.8
Petrol II	95 0	...	...	...	...	...	...	...	...
Diesel III	37.0	...	...	...	...	...	..	...	...
(Dutch florins.)									
Rumanian :									
Petrol 60 H. P.	58.5	0.28	...	...	16 4	2.24	0.02	...	67.7
Petrol 70 H. P.	71.5	...	...	0.80	20.0	2.32	0.02	...	76.9
Petrol 90 H. P.	68.5	...	...	...	19.0	2.16	0.02	...	60.7
(Gold-leis.)									
Finnish :									
Petrol	39.1	...	1.273	....	13.87	7.80	...	...	131.2
Petrol	45.0	...	...	...	...	...	...	...	...
Diesel	32 0	...	0.623	...	33 81	2 97	...	...	150.0
(Finnish marks.)									
Italian :									
Petrol	25.0	...	...	...	...	...	...	...	...
Diesel	35.0	...	...	...	...	...	...	...	...
(Lires.)									
Swiss :									
Petrol	56.0	...	0.0214	...	31.00	0.45	...	...	38.3
Diesel	87 0	...	0.027	...	11.94	1.07	...	...	38.3
(Swiss francs.)									
Yugoslav :									
Petrol, 1 trailer	60.8	...	...	...	562	...	...	...	210
Petrol, 2 trailers	57.5	...	..	...	...	600	...	...	210
(Test results. Yugoslav dinars.)									

motor-coach operation.

Km.				Cost of rail motor-car		Number of cars.	Weight of one car in metric tons (empty).	Cost per kgr. in American dollars.	*Remarks.*
Cleaning and upkeep.		Total.	Total in American dollars.		American dollars.				
tor.	Trailer.								
0.7	77.4	670.3	13.54	...	...	55	31.2	...	
...	...	...	...	...	...	1	...	...	
..	...	...	..	50 000	13 355	40	...	. .	
...	...	...	...	...	...	6	...	...	
.0	...	30.90	12.43	46 300	18 622	13	34.0	0.55	
...	...	...	...	...	...	...	32.0	0.79	
...	...	...	...	...	...	8	17.0	1.12	
.8	4.0	35.23	7.05	42 250	8 450	21	15.1	0.56	Trailer : 8 to 10 000 gold-leis (4 to 5 000 dollars); 11 t. (0.36 to 0.45 American dollars per kgr.).
.32	4.0	40.35	8.07	45 210	9 050	...	16.1	0.56	
.18	4.3	36.73	7.35	58 210	11 640	...	17.2	0.64	
.90	...	282.7	7.15	521 789	13 213	2	20 5	0 64	
...	...	...	...	...	...	...	...	...	
.39	...	202.8	5.13	1 014 293	25 662	1	33 2	0.77	
...	...	...	...	240 000	13 032	2	23.0	0.56	
...	...	...	...	400 000	21 720	2	18.0	1.21	
...	...	...	..	135 000	26 042	1	22.0	1.18	
...	...	...	...	285 000	54 970	1	50.0	0.91	
185	...	957	16.35	850 000	14 535	2	17.8	0.82	Trailer : 382 000 dinars (6 559 American dollars); 11.3 t. (0.578 dollars per kgr.).
227	...	1 038	17.74	...	...	...	...	...	

gers of a single class (3rd), and is capable of hauling one or two trailers, each of 50 seats, of a special light type.

This type of rail motor-car is only occasionally fitted with Diesel engines.

The buffers and couplings of such a rail motor-car are of the standard railway type; the lighting is always electric, and the heating is effected by the engine cooling water.

2. The *heavy type* of rail motor-car is at present much less widely used. Such a car, with a weight unloaded of 25 to 40 t. (24.6 to 39.4 Engl. tons) and more, with a Diesel engine having 6 or 8 cylinders, of from 180 to 250 H.P., and with 4 axles, is capable of hauling two or three trailers of a standard railway type at the speed of 60 to 70 km. (37.3 to 43.5 miles).

Here electrical transmission is employed as well as mechanical transmission.

All the other technical data for this type are approximately the same as for the light type.

3. *The organisation of the service* of all types is essentially the same.

The rail motor-car is employed either alone or as a train with one or two trailers, according to traffic requirements. The total seating accommodation of such a train may run up to 200-230 (Danish, Rumanian and Swiss Railways), which is comparable to that of ordinary local trains.

The speed, in service, of the rail motor-cars usually attains 50 km. (31 miles) per hour; the acceleration of the rail motor-car being much greater than that of the steam locomotive, the average speed of rail motor-car trains does not differ much from their maximum speed.

4. Rail motor-cars are capable of climbing considerable gradients (up to 30 $^{00}/_{00}$ [1 in 33], for example) and usually serve branch lines, although there is a marked tendency on the part of some railway administrations to use them on main lines, in co-operation with fast trains, when they follow or precede these trains.

Rail motor-car trains are most frequently operated by a single driver and one or two guards, which is sufficient, as there is usually intercommunication between all the vehicles of the train.

The rail motor-cars are ordinarily housed in special depots. They are not kept in steam locomotive sheds except when their number is too small to permit the construction of separate sheds.

5. *The operating costs* of the rail motor-cars are very variable. Unfortunately the small number of replies received does not permit us to formulate final conclusions in this regard.

It is found, however, that these costs are lower than those of local steam trains.

Several administrations state that the use of rail motor-cars on branch lines has enabled them to meet and even reduce tramway and motor-bus competition.

Finally, it may be said that several administrations which use heavy rail motor-cars with Diesel engines show a marked tendency to increase the power of their engines.

Appendix I.

Detailed questionnaire with regard to question XX.

LIST OF QUESTIONS.

I. — Description of rail motor-cars.

A. — What are the various types of rail motor-cars or vans which you have in service?

B. — For each type please send the following data and information :

1. Number of your rail motor-cars :

a) with explosion engines;

b) Diesel type.

For A and B, please state :

a) with simple mechanical transmission;

b) with electrical transmission and control.

For each type state :

the number of 2-axle cars;
the number of 3 axle-cars;
the number of 2-bogie cars;

2. Diagram of rail motor-car (elevation and plan), preferably on the scale of 1 : 100.

Please state :

number of motor axles,
number of coupled axles,
gauge of track,
total wheel-base,
distance between centres of bogie axles,
diameter of wheels,
length over buffers,
length of body,
internal width and height of compartments,
minimum radii of curves.

3. General arrangement drawing, with sections, of the motor and accessories (Preferably to scale 1 : 10).

It would be desirable to have separately the most characteristic details of construction, for the rail motor-cars formed of an independent engine, or of a motor truck which is almost independent, and a car coupled to the said engine or else carried at one end by the chassis of the engine and at the other end by an ordinary axle or bogie; please state the details of the assembly of the car with the engine.

4. Weight of the rail motor-car unloaded. Weight light of engine only, where it constitutes a separate chassis.

Weight in service, fuelled complete (water, fuel etc.), but without passengers, luggage and mails.

Weight in service, fuelled complete, and with maximum load of passengers, luggage and mails.

Distribution of the aforesaid weight on each pair of wheels.

Should the weight per pair of wheels be limited by the condition of the track or bridges, please state :

the maximum admissible load on the rails;

the weight of the rail per metre, length of rail and number of supports (sleepers) for each rail.

5. Please state also what would be the approximate weight unloaded of a carriage or van of your standard type closest, from the point of view of comfort, strength, good riding, etc., to the rail motor-car having the same capacity for luggage and mails.

6. What classes are provided? Seating accommodation for each class. Maximum load limit or capacity of the luggage compartment, and, if it exists, the mail compartment.

7. Braking methods : screw, lever or steam brakes, etc., continuous braking (on what system?). Please state for each braking apparatus if it acts on all the wheels of the rail car or on part only.

8. Heating system of the rail motor-car and trailers.

Lighting system for the car, the driver's compartment, the outside head and tail lights.

9. Is the rail motor-car fitted with the standard buffers and couplings used on your system? Or have you adopted equipment of special type for service alone without trailers, or with trailers of special construction? In the second case, please give a sketch of this.

10. Where internal combustion or Diesel engines are used, with either mechanical or electrical control, please send a detailed description of the system, with the characteristics of the engines and data relating to the transmission gear.

11. Position of driver's compartment or compartments. Is there a single compartment, at one of the ends? With what arrangement for running backwards, if this is permitted? Or are there two similar compartments with identical equipment, one at each end?

For the rail motor-cars having at one end the engine complete, and at the other end an additional compartment occupied by an employee acting as driver of the engine during running backward, please state the equipment of the other compartment and the means of intercommunication between this compartment and the engine compartment: electric bell, whistle (compressed air); operation of the regulator (closing only, or both opening and closing), operation of continuous brake; of screw brake (acting on all the wheels of the rail motor-car), etc.

Please add to your reply the specification and technical conditions for the materials used in the construction of the rail motor-cars.

II. — Service Organisation.

MODE OF USE.

2. State for each of your types of rail motor-car, please state if you use them exclusively by themselves, or with trailers:

In the second case, is there communication between the rail motor-car and the following car, and between the individual trailers. Is stock with continuous braking exclusively used or not?

2. State for each of your type of rail motor-car (including motor vans, mail vans, motors, etc.), if driving is entrusted to two men or one only.

State the number of men of the operating department which you use in addition to the above-mentioned traction staff:

a) for the rail motor-car running alone,

b) for the motor-car hauling one or more trailers.

In the second case, does the number of employees depend on the number of cars, the gradients on the line, the existence or otherwise of intercommunicating gangways, the working or not of the continuous brake?

3. For the rail motor-cars which have a single compartment for the driver at one end, please say if at the end of the run the rail motor car is always turned on a turntable.

In the contrary case, what is the maximum speed which you authorise when the rail car is running with the driver's compartment behind?

With a view to avoiding shunting at the end of the run on shuttle services, do you permit the running of rail motor-cars pushing one or more carriages? What is, in this case, the maximum speed allowed?

4. Diagrammatic profile of the lines or sections of lines served by the rail motor cars, showing the distance between stations, differences of altitude, maximum gradients and their length, longest gradients and their profile, minimum radius of curves.

5. Enumeration of the services daily effected by the rail motor-cars on your system, stating the types of rail motor-cars respectively employed, the terminal stations and the mileage of each run, the total run per day of each of your types of rail motor-car and of the general total.

Are certain of these services divided into two stages, effected by two different rail motor-cars, on account of the length of the run. Please state the maximum daily mileage for the rail motor-cars of your different types, or, better, send if possible the mileage of your rail motor-cars in the form of a graph.

6. Average weight unloaded and in service, seating accomodation for each class, number of axles of the trailers ordinarily hauled by the rail motor-cars.

7. For each of the runs effected by your rail motor-cars (see No. 5) please state :

a) the average and maximum number of trailers, and the total corresponding weight (including passengers, luggage, etc.) ;

b) the time-table, showing stops and arrival and departure times.

8. For each type of rail motor-car on your system, please state, the number at present existing, the date of construction of the oldest and newest, the number of units effectively employed in daily service, the average number of units immobilised for washing, repairs, any replacements, annual mileage per unit.

9. From the point of view of passenger transport conditions, do you notify the public which are the runs provided for in the time-table and effected by means of rail motor-cars?

Are they considered as trains having limited seating accommodation? In the contrary case, if there is an unusual rush of passengers, do you send off another train (relief train) hauled by another rail motor-car or by a locomotive, or do you simply send a locomotive instead of the rail motor-car with a larger number of passenger cars?

Are the journeys operated by rail motor-cars subject to predetermined connections with other trains, or are they exclusively local in character, independent of any connection?

10. Is your programme for the use of rail motor-cars on secondary lines limited to certain extra services interpolated between the pre-existing services worked by steam locomotives?

Have you used rail motor-cars to cover the complete passenger service on some branch or small line?

Have you been obliged in this case to form goods trains hauled by locomotives when, formerly, you had mixed trains? How have you worked cattle and fast goods trains?

11. Does your service programme comprise an extended use of rail motor-cars on main lines?

If so, what would be essentially your object?

To meet the competition of tramways or other short-distance means of communication? Or rather to improve, at moderate cost, certain communications of a local or suburban character?

Have you, perhaps, thought of using the rail motor-cars to create, on several main line sections, services stopping at all stations a little before and immediately after the passage of long-distance expresses, so as to improve the communications of the less important centres without increasing the number of stops of the express trains?

12. Have you also considered using the rail motor-cars to establish, at moderate cost, temporary experimental communications, so as to find out what the passenger movement is, with a view to transferring them, after a certain experimental period and in case of good results, to locomotive-hauled trains, or doing away with them in the contrary case? Have you any example?

13. Have you assigned, for preference, rail motor-cars to certain local runs which are not worked on Sundays and holidays?

Do you make use of these days out of service for washing and maintenance of the cars, so as to work the service with a smaller number of reserve rail motor-cars?

14. Do your rail motor-cars use the locomotive depots for stabling and maintenance, or have separate depots been provided?

Are they looked after by the same staff of the traction service as attends to the locomotives, or have you a specialist staff?

III. — Technical and economic results.

1. For each of your types of rail motor-car please state the maximum distance which you can in practice run in regular service, between taking water and fuel, etc.

2. Please give some information regarding the most difficult services which you have been able to work with rail motor-cars, from the point of view of tractive effort, output of motor, and speed (load hauled), average and maximum gradient and its length, maximum run without stop, average effective speed in full running order attained without effort on the said gradient, etc.

Maximum speed attained on the level, with good conditions of stability, and with regular running of the motor.

3. What observations have you to make on the results obtained in current service from the point of view of power, and above all of flexibility in use, with regard to service requirements?

With regard to the load and the schedule mentioned in Question II, have you found difficulty in securing regular running? Can you make up lost time?

4. Have you experienced difficulties in motor upkeep, in view of the special construction, generally less robust than that of locomotives?

To facilitate the upkeep of the machines, have you spare motor trucks, in the case of rail motor-cars with motor trucks which can be removed from the main frame?

If it is necessary to stable and overhaul the rail motor-cars in the locomotive depots, and in view of the connection of the interior of the car with the mechanical portion, have you not experienced trouble due to the deterioration of the car, particularly the upholstery and fittings, and the difficulty of keeping them in a good state of cleanliness?

Have you had trouble due to space taken up in the depots, by reason of the length of the rail motor-cars?

6. Have you been frequently obliged to take out of the working the rail motor-cars and replace them by locomotives, on the occasion of a large rush of passengers, either of a periodic nature (market days, holidays, etc.) or during certain seasons (seaside services, holidays, etc.), or accidentally?

7. Have you found it advantageous to reduce the classes to one only, even for the trailers?

8. Has the number of runs of rail motor-cars interpolated between pre-existing trains given rise to congestion, difficulties with station service, delays for the principal trains on the lines carrying a heavy express and goods train traffic?

9. Average consumption of fuel per kilometre, including consumption for starting and stops.

10. Average fuel cost per kilometre, also cost for lubricating and lighting material, water, running staff, cleaning, maintenance of the mechanical portion (including small and large repairs), and the upkeep of the car, all per km.

11. Average purchase price of the rail motor-cars of your various types, in comparison with the cost of the locomotives referred to in the preceding question.

12. Have you in construction other rail motor-cars? Of what type? Are you thinking of extending their use?

PRINCIPAL DATA OF RAIL MOTOR CARS.

Principal data

Principal characteric data.	Italian State Railways.		Danish State Railways.		Netherlands Railways.	
	Petrol motor cars.	Diesel motor cars.	Petrol motor cars.	Diesel motor cars.	Petrol motor cars.	Diesel motor cars.
I. — Technical data.						
Series and type of motor-cars .	N 8701	N 8801 (on test).	Ma, Mc, Me and Mf.	MR.	Type I and II.	Type III
Kind and system of motor .	Petrol.	With Diesel engine.	Petrol.	With Diesel engine.	Petrol.	Diesel.
Total number of axles. . . .	4 axles (2 bogies).	...	Ma, Me and Mf 2.	MR 4	4	2
Number of driving axles . . .	2	...	1	2	2	1
Track gauge, in metres . . .	1.435	1.435	1.435	1.435	1.435	1.435
Total wheelbase, in metres . .	12.50	8.55	Ma 5.450; Mc 8.200 Me 5.900; Mf 5.900	3.400	13.500	6.000
Length of body, in metres . .	13.80	9.10	Ma 7.205; Mc 12.480 Me 8.905; Mf 8.905	17.920	16.350: 16.700	10.260
Kind and system of motor.	...	...	...	...	...	...
a) Number of cylinders . . .	...	...	6 2 motors.	6	6	6
b) Diameter in millimetres .	...	...	120	115	...	...
c) Piston stroke in millimetres	...	...	170	180	...	...
d) Normal number of r. p. m.	...	...	1200	1100	2000	950
e) Power, H. P.	...	100	...	180	70	75
f) Weight of motor, in kilogrammes.	...	...	...	...	650	750

ail motor cars

Finnish State Railways.		Rumanian State Railways.			Swiss Federal Railways.		British Railways.		Yugoslav State Railways.
etrol notor cars.	Diesel motor cars.	Petrol motor cars.			Petrol motor cars.	Diesel motor cars.	Steam cars.	Petrol motor cars.	Petrol motor cars.
...	...	...	...	...	N 9911-9912 CFm 1/2.	N 9901 CFm 2/4	Sentinel and Clayton.	...	...
etrol.	Diesel.	...	Petrol.	...	Petrol.	Diesel.	Steam.	Petrol.	Petrol.
2	4	...	2	...	2	4	...	...	2
1	2	...	2	...	...	...	...	...	1
.524	1.524	...	1.435	...	1.435	1.435	...	...	1.435
2.000	15 15	...	8.000 à 9.000	...	9 200	13.500	...	...	6.700
1.600	15.450	...	12.075	...	12.590	19.000	...	...	10.806
AEG. notor	Diesel-electr. Vesteras A/B motor.	60-H.P. Westinghouse.	70-H.P. De Dion	90-H.P. Westinghouse.	Saurer.	Sulzer.	...	...	...
6	6	4	4	6	8	8	2	6	6
20.6	165	140	150	140	120	215	170-152-177	...	130
170	200	160	180	160	180	300	228-177-254	...	160
350	600	950	1100	1050	1200-1000	550	...	1000	1000
75	90	60	70	90	120-100	250	...	105	85
2 500	...	...	...	...	...	6 400	...	...	...

Principal characteric data.	Italian State Railways.		Danish State Railways.		Netherlands Railways	
	Petrol motor cars.	Diesel motor cars.	Petrol motor cars.	Diesel motor cars.	Petrol motor cars.	Diesel motor cars.
I. — **Technical data** (*continued*).						
g) Fuel, quality and guaranteed consumption.	...	Petrol, 400 gr./km.	...	Gas oil, 600 gr./km.	Petrol, δ = 0.74, 280 gr./H.P -h.	Gas oil, δ = 0.86 210 gr./H.P.-
h) Capacity of fuel tanks, in litres.	...	...	...	...	550	250
Type of mechanical transmission :	...	...	...	...	...	...
a) Number of speeds	...	3 or 4.	...	...	4	4
b) Type of coupling of speeds.	...	...	...	...	4 A.E.G. friction clutches.	...
c) Reverse running.	...	...	...	...	Gearing.	Gearing.
d) Clutch	. .	. .	...	...	By discs.	
Type of electric transmission :						
a) Kind of current	...	...	...	...	...	...
b) Type of generator	...	...	...	...	...	...
c) Voltage.	...	...	...	...	...	...
d) Control.	...	...	...	...	...	...
e) Number of electric motors.	...	...	...	...	...	...
Weight of motor car, empty, in metric tons.	...	...	Ma Me Mc Mf 11.0-19.3-13.5-14.8	MR	Type I, 34.0 Type II, 32.0	Type III, 1
Weight in full gear of motor car (without passengers nor luggage), in metric tons.	23	18	11.4-19.8-13.9-15.2	42.6	...	. .
Number of available seats 1st class.	...	...	..	...	...	...
2nd class.	...	...	...	...	T. I, 25+10	...
3rd class.	70	46	24, 50, 33, 33	60	T. I, 40+10 T. II, 76+34	T. III, 43+

Finnish State Railways.		Rumanian State Railways.			Swiss Federal Railways.		British Railways.		Yugoslav State Railways.
Petrol motor cars	Diesel motor cars.	Petrol motor cars.			Petrol motor cars.	Diesel motor cars.	Steam cars.	Petrol motor cars.	Petrol motor cars.
Petrol, 250 gr./ H.P.-h.	Gas oil, 210 gr./H.P.-h.	585 gr./km.	715 gr./km.	685 gr./km.	Petrol, 0 7	Gas oil, δ = 0.8	Coal, 3.429 kgr./km.	Petrol, 0.537 kgr./km.	Petrol, 0.608-0.575 kgr./km.
..	...	...	...	...	250	350	...	...	...
...	...	...	...	..	9911, 9912	...	Gear or chain.	...	Gearing always in mesh.
4	...	...	...	...	3 or 4	...	...	...	4
By ompressed air.	..	...	...	...	Mechan., oil.	...	...	...	By compressed air.
Mechan.	...	..	...	...	Mechan.	...	...	...	Gearing.
...	..	...	...	...	...	...	...	...	By friction, by compressed air.
...	Continuous.	Continuous.			..	Continuous.	...	...	..
...	...	Compound.			...	...	...	...	...
...	620	500	500	550	...	600	...	..	...
...	Electric.	...	...	...	...	...	..	...	...
...	1	2 to 35 H.P.	2 to 35 H.P.	2 to 50 H.P.	...	...	...	...	...
20.3	23.2	15.1	16.1	17 2	21.0	58	25 2-25.2-28.0	17.1	...
20.5 nd 20.2	33.2	15.4	16.4	17.6	23	60	27.2-30.2-31.0	...	16.7
...	...	..	...	...	...	...	...	...	...
42	62	48-60	48-60	48-60	48	50	...	...	12
...	...	...	...	...	...	...	...	...	40

Principal characteric data.	Italian State Railways.		Danish State Railways.		Netherlands Railways	
	Petrol motor cars.	Diesel motor cars.	Petrol motor cars.	Diesel motor cars.	Petrol motor cars.	Diesel motor cars.
I. — Technical data. *(continued).*						
Total number of passengers	70	46	24, 50, 33, 33	60	Type I, type II 85, 110	Type III 67
Approx. volume reserved for luggage.	...	...	2 000 kgr.	2 000 kgr.	...	...
Total weight of motor cars with passengers and luggage, in metric tons.	28	21	13.9-23.8-17.0-18.5	45.0	40 4, 40.3	22.0
Number of units per type	2	2	40	6	3 10	8
Braking system	Screw brake. Continuous Westinghouse brake on all wheels.		1) Lever brake. 2) Knorr air brake.		1) Westinghouse brake 2) Screw brake on bot wheels of one axle.	
Lighting system	...	...	Electric.		Electric (2 paraffin lamps as standby).	
Heating system	With motor cooling water.		With motor cooling water.		With cooling water.	With cooli water.
II. — Service organisation.						
Authorised maximum load on rails, in metric tons.	16	16	...	...	20	20
Weight of rails, kgr. per metre.	36	36	32	32	46	46
Length of rails, in metres	9	9	10.97	10.97	18	18
Number of sleepers to each rail	12	12	15	15	24	24
Drawing and buffing gears	Standard.		Series Mf and MR, standard. The others, special.		...	...
Number of driver's compartments.	2	2	1	2	2	2
Number of trailers	0	0	0 or 1	0 or 1	0	0
Number of drivers	1	1	1	1	1	1
Number of men of Traffic Dept. on motor car alone.	1	1	1	1	1	1

Finnish State Railways.		Rumanian State Railways.			Swiss Federal Railways.		British Railways.		Yugoslav State Railways.
Petrol motor cars.	Diesel motor cars.	Petrol motor cars.			Petrol motor cars.	Diesel motor cars.	Steam cars.	Petrol motor cars.	Petrol motor cars.
42	62	48-60	48-60	48-60	48	50	...	...	52
None.	None.	...	...	...	1.0 t.	1.5 t.	...	...	...
23.8	38.2	...	...	...	26.2-26.0	63	31.2-34.2-35.0	...	...
2	1	21 (Total.)			2	1	24-20-11	1	2
Westinghouse brake (on all wheels).		1) Hand brake. 2) Böcker air brake (on two axles). 3) Electric brake (tramway type).			2 screw brakes.		...	1) hand. 2) air.	1) air (Knorr) 2) hand.
Electric.		Electric.			Electric.		Electric.		Electric.
With cooling water (ordinary stove in reserve).		With cooling water.			Exhaust gases.	With cooling water.	Steam.	With cooling water.	With cooling water.
...	...	...	...	...	...	...	...	...	...
22.3	22.3	...	...	...	...	...	...	...	...
9	9	...	...	...	...	...	...	...	...
16	16	...	...	...	...	...	..	...	...
Standard.		Special.			Standard.		Standard.		Standard.
2	2	...	1	...	2	2	...	...	2
0 or 1	0 or 1	...	0, 1 or 2	...	0, 1, 2 or 3	0, 1, 2 or 3	0 or 1	0 or 1	0, 1 or 2
1	1	...	2	...	1	1	2	1	1
...	...	...	1-2	...	1	1	1	1	1

Principal characteric data.	Italian State Railways.		Danish State Railways.		Netherlands Railways.	
	Petrol motor cars.	Diesel motor cars.	Petrol motor cars.	Diesel motor cars.	Petrol motor cars.	Diesel motor cars.
II. — Service organisation *(continued)*.						
Number of Traffic Dept. men on motor cars.	2	2	2	2	...	...
Total daily run in kilometres .	34	...	5 878	1 452	1 950	876
Dates oldest and latest designs of cars were built.	1924	...	1925-1929	1928	1923-1924	1927
Annual run per unit, in kilometres.	...	...	...	...	50 000	37 800
Rush hour measures	Steam trains.		Steam trains.		Steam trains.	
The use of motor cars on main lines.	No.	No.	Yes.	Yes.	Yes.	Yes.
Stabling of cars	Locomotive sheds.		Locomotive sheds.		Special sheds.	
Maximum run without refuelling, in kilometres per hour.	100	100	250	400	Type I Type II 470 580	675
Maximum non stop run, in kilometres per hour.	7	...	10	10	...	...
Maximum speed on gradients in kilometres per hour.	30	...	20	20	...	...
Maximum speed on level in kilometres per hour.	50	50	Mf 75, and all others 70.	70	..	...
Making up lost time	Difficult.		Possible.		Possible.	
Any difficulties in upkeep of cars?	No.	...	No.	No.	No.	Yes.
Any difficulties when stabling cars in locomotive sheds?	No.	...	No.	No.	Yes.	Yes.
Average purchase price of cars.	240 000 lires	400 000 lires.	50 000 Dan. crowns.	120 000 Dan. crowns.	Type I : D. fl. 46 300, 1923. Type II : — 63 000, 1924. Type III: — 46 500, 1927.	
Other cars in course of construction.	...	Diesel motor cars under test.	4 with 2 motors.		7 twin-motor cars. 6 single-motor cars.	
Any intention to extend their use.	No.	Yes.	Yes.	Yes.	Yes.	...

Finnish State Railways.		Rumanian State Railways.			Swiss Federal Railways.		British Railways.		Yugoslav State Railways.
Petrol motor cars.	Diesel motor cars.	Petrol motor cars.			Petrol motor cars.	Diesel motor cars.	Steam cars.	Petrol motor cars.	Petrol motor cars.
...	...	...	2	...	1	1	1	1	1
...	...	...	538-575 tr.-km.		...	...	...	...	(Under test.)
1925	1928	...	...	...	1925	1925	1925-1928	1923	1928
...	...	40 000 for 60 and 70 H.P. 50 000 for 90 H.P.			34 990	33 720	62 000	62 000	(Under test.)
Steam trains.		Increase the number of trailers.			Steam trains.		Steam trains.		...
No.	No.	No.			No.	No.	...	...	...
Locomotive sheds.		Special sheds.			Locomotive sheds.		Special sheds.		Special sheds.
...	...	60 H.P. 200	70 H.P. 250	90 H.P. 300	300	350	...	...	...
...	...	...	...	...	...	...	...	...	...
15-26	15-26	25	30 and 45		...	40	...	...	...
40-44	50-56	40-45	45-50	60-65	50	60	64	64	60
...	...	Possible.			Possible.		Possible.	...	...
No.	No.	...	No.	...	Yes.	Yes.	No.	No.	No.
No.	No.	...	Yes.	...	No.	No.	Yes.	Yes.	Yes.
521 789 Finnish marks.	1 014 293 Finnish marks.	42 250 gold-lei 60 H. P. 45 250 — 70 H. P. 58 210 — 90 H. H.			135 000 Swiss fr.	285 000 Swiss fr.	...	...	14 535 American dollars.
2 rail motor cars.		120 and 200-H. P. rail motor cars.			...	1 Diesel motor van, 420 H.P. 1 Diesel rail motor cars 300 H.P.	...	...	...
Yes.	Yes.	...	Yes.	...	No.	Yes.	...	...	Yes.

APPENDIX III.

Table of the data relating to boilers and engines of the English steam rail cars

Type of rail car.	Sentinel-Cammell.		Clayton.
	Chain driven.	Gear driven.	Direct coupling.
Type of boiler	Vertical water tube boiler.		
Boiler pressure, in kgr./cm²	19.25	21 0	19.25
Total heating surface, in sq. metres	6.4	6.6	6.3
Superheating surface, in sq. metres	..	...	...
Diameter of cylinders, in millimetres	170 vertical.	152 horizontal.	177 horizontal.
Expansion	Simple.	Simple.	Simple.
Piston stroke, in millimetres	228	177	254
Diameter of driving wheels	...	...	...
Type of transmission of motion	Chain.	Gear.	Direct coupling.
Type of valve gear	Valves.	Valves.	Cylindrical slide valve.
Kind of fuel	Coal.	Coal.	Coal.

[621 .33]

REPORT No. 1

(Europe)

ON THE QUESTION OF THE ELECTRIFICATION OF SECONDARY LINES (SUBJECT XIX FOR DISCUSSION AT THE ELEVENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION) (1).

By L. SEKUTOWICZ,
Manager of the « Omnium Lyonnais », Paris.

Figs. 1 to 7, pp. 508 to 524.

Introduction.

Definition of the question.

Importance of the economical and financial point of view.

Extent of the secondary lines.

Present position of the electrification of secondary railways.

FIRST PART.

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CHAPTER I. — *Advantages of electric traction on secondary lines.*

Technical advantages.

Economical advantages.

CHAPTER II. — *Principal systems to be considered.*

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Continuous high tension.

Accumulators.

Selection of a system.

CHAPTER III. — *Standardisation of the rolling stock.*

SECOND PART.

Possibilities of using electric traction on secondary railways.

Position of the subject.

Case of a new line.

Case of an already existing steam line.

CHAPTER I. — *Fuel consumption of steam locomotives.*

Ratio of the total weight of a train to the weight hauled.

Tractive resistance of a line.

Work done in hauling the trains.

Coal consumption.

CHAPTER II. — *Electric energy used for traction and savings secured in fuel.*

Energy consumed.

Ratio of the coal and energy consumption for a given line.

CHAPTER III. — *Comparison between the gross saving to be realised on the fuel compared with the financial charges through electrification.*

THIRD PART.

Description of a number of electrified secondary lines.

Continuous current. — Belgian Light Railways. Interurban service of relatively great density. 600-volt continuous current.

Light Railways (Jura system). 1 500-volt continuous current.

Le Fayet to Chamonix.

North of Milan Railways. 3 000-volt continuous current.

Alternating current. — Camargue Railways. Monophase current at 25 periods.

Rhætian Railway.

Accumulator traction.

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(1) Translated from the French.

INTRODUCTION.

It is difficult to define with accuracy what are secondary lines. The gauge is not a satisfactory criterion in this case, as many branches of main lines belonging to the great Companies are of very secondary importance, and contrariwise, there exist narrow gauge lines of public utility which carry a greater traffic than that of certain of the great Companies. These secondary lines are operated in some cases with faster and more comfortable trains than those used on main lines of secondary order.

Fundamentally the problem posed amounts to an investigation into electric traction in general, leaving on one side the main lines with powerful engines running at high speed, and on the other urban tramways, metropolitan railways and lines operated with special stock (rack railways, funicular railways, etc.). The traffic on the lines investigated will therefore in general be less intense than that of the great Companies, and these lines will be of a light railway character, that is to say built more lightly with steeper gradients, curves of smaller radius, and less powerfull locomotives.

All these conditions except that relating to the tractive resistance of the train are unfavourable for electrification, especially from the financial point of view.

The characteristic features of electric traction, is to involve the *locking up of large sums of capital*, and to necessitate as a consequence the recovery by economies in the *operating expenditure* (fuel, labour, maintenance) of the financial charges which result therefrom. The additional capital immobilised through electrification depends but little upon the traffic; the financial equilibrium of the operation is the more easy to attain as the traffic is greater as Mr. Parodi has shown in the case of the great Companies.

Consequently for any well determined application electrification only commences to pay after a certain daily movement, and this limit is rarely reached in the case of the secondary lines.

For equal traffic the operation is more attractive for a line of difficult profile.

Finally it is necessary to distinguish carefully the case of a new line to be built from that of an existing line to be electrified.

If everything is to be built new, for example in a new country, it is possible to some extent (taking care to prevent the operation of the line becoming too difficult or too expensive) to allow steeper gradients and smaller radius curves.

The saving in the first cost which results makes the financial operation easier. But the principal feature is that it is possible in this case to purchase rolling stock, locomotives and motor coaches without having to scrap the old rolling stock, not yet fully depreciated.

On the other hand if the line is already in operation, scrapping the old rolling stock if it cannot be used elsewhere, forms a very heavy charge.

This financial equilibrium is an essential condition in every case. But in certain countries another consideration also of an economical character has to be considered. It consists of the advantages to be obtained by substituting for coal a raw material imported, electric energy developed hydraulically in the country itself. The advantage however only exist from the point of view of the balance of payments of the country and countries abroad, provided the electrification does not make it necessary to purchase outside rolling stock of a total value higher than the cost of the coal which would have had to be imported during the period of the use of this material if the line has been steam operated.

It has been recognised that this condition is almost always realised but it is so much the more so as the traffic is heavier and the interest on the operation is only appreciable in absolute value on a line with heavy traffic. Thus the electrification of all the secondary French Railways would only have made it possible to save, if feasible and if all the energy used had been from hydro-electric stations, 450 000 tons of coal per annum (1).

A consideration of general interest of another kind has to be considered as regards electrification : The question of national defense. A country without coal, but with ample water ressources such as Switzerland, can consider it to be less dangerous to electrify its lines which makes them more vulnerable than to remain under the dependance of the good will of its neighbours. A country with coal resources even of insufficient quantity, will prefer on the other hand not to electrify those of its lines even if secondary which are not out of danger of being reached by a possible enemy.

In the part which precedes we have brought out side by side the financial charges with the various *reductions cf operating expenditure* amongst which we have not mentioned the suppression of a man per train often accomplished. It is also necessary to take into account certain causes by which the *receipts are increased* with electric traction.

This latter constitutes a progress from the point of view of speed and of comfort, and it generally results in an increase in passenger travelling.

Without taking into account the extraordinary growth noted when the urban tramways were electrified in the case of some suburban or interurban lines, very valuable improvements have been obtained (1).

It may even be that the greater speed and the improvements in comfort have an absolutely decisive influence from the point of view of the receipts, for example on a line already in competition with road transport. In certain cases it has been possible to get back passengers who were leaving day by day the railway.

Importance of the secondary railways.

The consequences of the War have been so disastrous for transport undertakings and especially for the secondary lines that one is tempted to ask if our work is one of any utility.

The decline of the railway is in fact much discussed in all countries. Certain wild spirits already see the main lines replaced by « motor roads » without taking the trouble to ask themselves what would be in time of war the position of countries which do not produce petroleum, and who have also abolished their railway systems.

We think on the other hand that the essential organs of our civilisation are and always will be necessary. The railway had almost killed the road. The automobile has brought it back to honour. In its turn it threatens the railway. But owing to the congestion resulting from road transport in the cities it is seen that bulk transport will remain to the railways. It is none the less true that many lines and even secondary railway systems built in certain countries rather for electoral and political or for speculative reasons will disappear. It could not ever be a question of fitting them out for electric traction. On the other hand such lines in hilly country rich in water power have the conditions required for electrification. This will often be the case in new countries and in the colonies.

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(1) The great railway systems use 7 200 000 tons.

(1) In this way the Belgian Light Railways inform us that on a line 28 km. (17.4 miles) long, starting from Brussels, the electrification has made it possible between 1909 and 1929, to quintuple the number of trains and to carry about four times more passengers than when steam working was in operation.

A few figures will demonstrate the relative importance of the question we are now considering.

In Switzerland in 1920, the secondary railways extended to a length of about 2 000 km. (1 240 miles), 1 500 km. (932 miles) of which were narrow gauge and cost 300 millions of Swiss francs. On the 2 000 km. more than half [1 300 km. (808 miles) about] were electrified.

In Belgium, the light railway systems have, in 1925, a total length of 4 500 km. (2 800 miles) of which 432 km. (268 miles) were worked electrically and 126 km. (78 miles) with mixed traction. (This system cost at the begining of the War, more than 350 millions of gold-francs.)

Germany had before the War 10 700 km. (6 650 miles) of secondary lines 6/10 of which were narrow gauge, and this system cost 726 millions of gold-marks.

France had at the same time 19 000 km. (11 800 miles) of secondary lines which cost 1 600 millions of gold-francs and in 1925 their length had grown to 22 600 km. (14 050 miles).

In Poland the light railways had in 1922 a total length of 2 767 km. (1 720 miles), 92 km. (57 miles) of which were electrified in the Lodz region, not including the electric system of Dombrowa and of Upper Silesia [115 km. (71.5 miles)].

In Italy there were in 1924, 5 000 km. (3 110 miles) of railways conceded to various companies (56 % being narrow gauge) and in addition 2 000 km. (1 240 miles) of interurban tramways and lines under construction. Gradients of 60 to 70 °/₀₀ (1 in 17 to 1 in 14) are found on the narrow gauge lines and 35 °/₀₀ (1 in 28) on the standard gauge. Of 111 secondary railways being operated 9 % alone have more than six pairs of trains per day.

These figures suffice to show that it is not possible to lightheartedly consider the disappearance of the secondary railway systems, and demonstrate the interest there is in doing everything possible to improve their situation.

Electrification however may not be usefully applied as we shall perceive, except on a small part of the existing secondary lines. It is only on about a 1 000 km. (621 miles), that is 6 % of the French system, that before the war the receipts per kilometre were of the order of 10 000 gold-francs (16 090 gold-fr. per mile) or more, with a train movement of only 10 to 12 trains per day in each direction, conditions which correspond generally with the present conditions, and make it possible to consider the electrification of an existing railway form the economical point of view.

In Switzerland on the other hand, the receipts per kilometre should reach 17 000 gold-francs (27 350 gold-fr. per mile) on the *whole* of the secondary lines, and the number of trains was 9 per day in each direction; thus 2/3 of this system had already been electrified.

The other countries lie between these two limits.

Present development of electrification of secondary railways.

The length of electrified secondary railways can be stated as follows :

Countries.	Dates.	Number of lines or systems.	Length in kilometres (in miles).	Observations.
Belgium	1928	...	581 (361)	
France	1926	14	1069 (664)	of which 144 (89.5 miles) under construction.
Italy	1924	18	882 (548)	
Switzerland.	1920	...	1067 (661)	

It will be seen that except in Switzerland the extent of the lines already equipped for electric traction is still very small for the reasons of economy sketched above and with which we will deal again.

FIRST PART.

Avantages and characteristics of the principal systems of electric traction.

CHAPTER I.

Advantages of electric traction on secondary railways.

The possibility of working heavy and fast goods trains and the introduction for the benefit of passengers of very frequent suburban services, or of international high speed services, has been among the first reasons which have led to the adoption of electric traction on the main railways. These advantages are only rarely found in the case of the electrification of the secondary railways. On the other hand the saving of coal which justifies at least partially from the financial point of view the electrification of the great railways would be relatively stronger in the case of the secondary lines because waste is more frequent, and the profile of the lines is more difficult.

The electric equipment does not however make it possible to build engines of tractive power similar to those used on the great systems, and which are rarely required on the secondary lines. On the other hand the competition of road transport which benefits from all the drawbacks of conveying passengers on the small lines by mixed steam trains, can be overcome effectively by using electric traction. In this way it becomes possible to concentrate the conveyance of goods to certain heavy infrequent trains, and to make the passenger trains fast and relatively numerous. The steam locomotive is not altogether suitable for this service; on the other hand electric traction makes it possible to form passenger trains built up of a rail motor coach either alone or coupled to several light trailers, it also makes it possible to haul goods trains by means of motor coaches fitted as brakes and carrying if need be passengers or useful loads. The adhesive weight utilises a notable proportion of the useful load which is particularly valuable in hilly country.

Petrol rail motor coaches also cover the working of light passenger trains, it is true, but with less flexibility, and this system in countries not having petroleum resources has an undoubted disadvantage from the financial point of view for the country concerned.

Electric traction is able, in brief, to use profiles without which in mountainous country the construction of railways would be impossible from the financial point of view. It also makes it possible on existing lines of easy gradients on condition that the traffic is sufficiently great, to modernise the transport methods and to meet competition. On the other hand for lines with very small traffic electric traction with overhead equipment would lead to ruin as regards financial returns. This would not be the case at least on lines with easy gradients if improvement in accumulators were to enable rail motors to be built at a reasonable cost price thereby making them suitable for operating purposes.

Independently of the advantages, in principle electric traction with overhead lines results in an undoubted improvement in the operating; but this improvement can only be calculated in each individual case. It depends upon :

— the possibility of reducing the number of men to one or two, instead of two or three per train;

— a better use of the staff, the commercial speed being higher, and interruption in the service shorter (taking water, lighting up, etc.);

— the total suppression of waste of coal, water and oil during stops;

— a better use of the rakes of vehicles which can work each day a much greater number of kilometres;

— a reduction in the maintenance cost for equal service on condition always that the rolling stock has been amply designed and is sufficiently powerful;

— ready use over lines with average traffic of lighter trains in greater numbers;

— better use on narrow gauge lines, for example in mines, of locomotives of considerably greater power than that of the ordinary type of steam engine;

— various other advantages (cleanliness, suppression of smoke, absence of sparks in the country).

CHAPTER II.

Principal systems to be considered.

The systems to be considered in practice can be reduced to two if particular cases be excluded such as rack railways or special services in which locomotives or motor coaches driven from accumulators are used. These are : the *monophase system* 16 2/3 or 25 periods, and the high tension *continuous current system* (1 500 volts and above).

Three phase current is not to be considered owing to the complications it involves in building the contact lines; these complications are the more inconvenient and expensive as it is a question of a line with less traffic.

Three phase current therefore should not be utilised except in the particular case in which braking by recuperation is necessary, and this is not usually done except in working over heavy gradients with the rack.

Monophase equipments.

The 50-period monophase current has been tested; but the use of this frequency increases the difficulties in building the motors. Getting good commutation forms in fact one of the most serious drawbacks from which this system suffers, when introduced.

The use of the frequency now become standard in the principal countries (50 periods per second) makes it possible to use a current supplied by the distribution scheme by means of simple static transformers which work without supervision and have a high efficiency.

It has been possible in fact in particular applications [Camargue Railway in France, for example ([1])] to feed a traction line by monophase current taken directly from a three phase distribution line. But the voltage rises due to starting and the unequal loading so introduced into the three phase distribution, limits to very particular cases, applications of this kind ([2]).

One is therefore obliged in most cases to feed the monophase traction line from *sub-stations* with rotary converter groups. It is then an advantage in spite of the progress realised in the construction of monophase traction motors, to profit from this circumstance and reduce the frequency to 25 periods or even to 16 2/3. So long as one does not decend below 25 periods, there is no difficulty as regards the proper working of incandescent lamps.

These rotary sub-stations have only a medium efficiency (70 to 80 % for example). The small annual use of them on the secondary lines makes them costly (supervision costs and financial charges).

On the other hand their number is reduced as they can serve a considerable distance seeing the distribution voltage is high.

On the monophase lines the overhead line is fed at a tension in practice of between 6 000 and 15 000 volts. This last tension is that used by the Swiss Federal Railways for their main lines. On the small lines 6 000 to 8 000 volts or, exceptionnally 10 000 volts are considered sufficient.

As is known the economical advantages of using high tension are obtained, other things being equal, for a lower value of the current when it is a question of continuous current than for alternating current.

In fact the impedance of the line and the low average value of the power factor result for a given value of a tension on the monophase line in a fall of tension greater at equal power transmitted than in the case of continuous current. It can be said approximately that the economic advantages are equivalent for a tension of 3 000 volts continuous current or 5 000 volts monophase.

The discussion of the relative advantages of traction by continuous current and of traction by alternating current has ceased to be a subject of discussion as these two systems have attained at the present time a degree of perfection sufficient to give equal statisfaction in practice. The monophase system still has to have on each train a heavy and costly transformer (especially inconvenient in the case of light vehicles) and motors the weight and cost of which exceeds by nearly 50 % those of continuous current motors of the same power. These drawbacks are much reduced in the case of locomotives. The influence of the monophase traction line on the telegraph and

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(1) Three-phase current at 25 periods from the Mediterranean Littoral Electric Energy Distribution System, is available.

(2) It would be possible, it is true, to convert the three-phase current into diphase, and use this current to feed the different successive and separate sections of the line. But this system would be too complicated to be of value.

telephone lines, is much more serious than in the case of continuous current; but this drawback is not very serious owing to the small powers used on light railways.

Monophase current which enables if needs be the use of voltages definitely higher than those of continuous current at high tension consequently offers the possibility of having only one sub-station to feed a secondary light railway system even of considerable extent, which simplifies the supervision and reduces the cost of the fixed plant. But recent progress in mercury rectifiers has in the case of high tension continuous current brought new facilities which have re-established almost the equilibrum between the two systems.

Continuous current equipment.

During recent years electric traction of secondary railways has been more and more often realised by means of high tension continuous current (1 500 or 3 000 volts). These relatively high voltages have only been made possible in practice by the use of commutating motors which with careful construction work without difficulty at 1 500 volts or even more per collector.

As regards the motors themselves, provided they are of sufficient power it is possible to go further and tests have been made with success of line voltages of 4 000 with motors working at 2 000, coupled together two in series. The equipments themselves and the difficulties resulting from flash overs and short circuits from the line make it necessary in practice not to deal in ordinary cases with such high voltages. Moreover the tension of 3 000 volts as we shall see further on is quite sufficient for the secondary lines, and the production of current at this voltage is particularly easy when mercury rectifiers are used to transform the three phase current supplied at high tension by the power distributing companies into the continuous traction current.

These apparatus, the efficiency of which is excellent (90 % and even 95 % over all) especially for the high tension on the continuous current side, are built today for all powers, as for low powers not exceeding 200 kw. use has been made with success for some time of valve rectifiers which are static appliances working without supervision and requiring at most a small ventilator to cool them.

Even in the large installations which require the use of metal tank rectifiers the accessory appliances are reduced to a few pumps and the automatic working of sub-stations so equipped is readily realised.

The result is that if the continuous current requires under equal conditions owing to its lower line tension the use of numerous sub-stations each feeding a more restricted area than in the case of alternating current, the drawbacks which results from the economic point of view are now much reduced.

A notable drawback of the equipment of high tension current results on the other hand from the need often experienced of producing on the trains themselves low tension current for lighting, heating, control of the contactors, etc.

If use is made of locomotives or single unit rail motor coaches this drawback can be reduced by employing mechanically or pneumatically controlled equipment which does not require control current or only needs for the control so little power that a few motor accumulators would suffice to give the low tension current needed for these accessories.

Under existing applications of electric traction for secondary railways the use of locomotives is rare and is only found when the traffic is heavy. As a rule rail motors known as « multiple units » are used and occasionally rail motor brakes are also employed for the goods working. The advantage of using « multiple units » is to be able to have in the same train a great number of motor axles, sometimes the whole, and thereby to get trains of high capacity able to run over heavy gradients.

As regards the overhead line supplying the traction current to the trains, practice is completely settled. Either simple suspension, or catenary lines are used, and the tendency in this latter case is to an extreme simplification of the suspension.

The endeavour is made to secure a line as flexible as possible, without « hard spots », and to avoid any heavy part liable to impart, by its inertia, shocks to the current collecting gear.

Catenary suspension is not essential when high tension current is used. It is only really necessary when the maximum speed of the trains considerably exceeds 50 km. (31 miles) per hour. It is, however, more flexible, and its cost price is not greatly higher.

The cost of the lines, to which must be added that of the electrical bonding of the rails, required to provide a suitable path for the return current, forms as we shall see, a large capital charge which plays an important role when the possibility of the electrification of a line is being discussed from the financial point of view.

The use of a third rail to supply current to the trains instead of an overhead line is very unusual in the case of secondary lines, because of the frequency of level crossings, which impose very inconvenient restrictions on this system. In any case, the third rail can hardly be utilised above 1 500 volts.

To sum the matter up, in the present state of practice, the choice of the traction system is determined primarily by the nature of the available supply of electrical energy.

If the line to be electrified is completely isolated from any other railway already electrically equipped, the choice lies between continuous high tension and single phase current.

The latter will be regarded with favour if it is a question of a secondary system of fairly large extent, easy to feed at a single point at which converge, for example, the different lines to be electrified.

If the line is *near a railway already electrified*, it will usually be advantageous to take current from the company operating such line.

If the secondary line is an extension of one or more lines of urban tramway, it will sometimes be necessary to supply it with continuous current at a pressure double that used on the tramway, which will permit, with four-motor equipments, operation either in town or outside with the same rolling stock, but at different speeds.

We cannot enter here into the details of the sub-stations, lines and rolling stock to be used on the secondary electrified lines.

Moreover, we shall give in the third part a short description of some of the specially interesting installations.

Accumulator traction.

The use of accumulator locomotives or rail motor-cars would have the greatest interest on light traffic lines. The advantages would be the same as those of the petrol rail motor-cars, but with the additional one of saving those countries which do not produce petrol the cost of importing liquid fuel; and on the other hand of utilising surplus current available during off-peak load hours in all power distribution systems.

A trial on a large scale of electric traction by accumulators on railway lines was carried out in Germany before the war. Since, various experiments have been made, in France and Italy in particular, on various secondary lines.

But the weight of the batteries becomes rapidly prohibitive as soon as it is a question of storing any considerable quantity of energy, and this dead weight, added to that of the train, increases the cost of operation if there are heavy gradients on the line. The losses in the battery itself further increase the consumption of energy per ton-kilometre.

There are, as is well known, two types of accumulators for traction purposes. The lead type, the older, has a better efficiency as regards energy (70 % instead of 60 %) but is heavier and less resistant to shock, and sudden demands. The nickel type is lighter (40 kgr. [88 lb.] per kw.-hour accumulable), but is dearer.

The tests carried out in Italy (1) since 1923 with lead batteries, generally of the Tudor type, have shown for a 5-hour discharge rate the following battery weights per kw.-h. accumulable :

Very light battery 26 kgr. (57 lb.);

Light battery 37 to 44 kgr. (81.5 to 88 lb.);

Heavy battery 93 to 95 kgr. (205 to 209.5 lb.).

The batteries tested represented a capacity of the order of 50 to 100 kw.-hours at the 5-hour discharge rate, and consequently are only applicable to light trains weighing from 10 to 40 tons on lines of easy profile, with speeds of 30 to 40 km. (18.6 to 25 miles) on the straight and on the level.

Recharged at night, only in exceptional cases during the day, with current at 0.05 lire per kw.-hour, the batteries can do from 100 to 200 km. (62 to 124 miles) and as an exception 300 km. (186 miles) per day on easy lines (2). The life of the negative plates at the 5-hour discharge rate is 500 to 600 hours for the lightest type, and 1 400 hours for the heaviest. Between two renewals of negative plates 45 000 to 70 000 km. (28 000 and 43 500 miles) can be worked.

In other words, the negative plates have to be replaced every five to eleven months of service, and the positives twice as often.

The batteries are maintained by contract by the supplier, and the total cost of operation would amount, for trains of 10 to 16 tons, to 2.20 lire, and for trains of 30 to 40 tons, 140 seats, to 2.70 lire.

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(1) Lo. Balbo, *Rivista dei trasporti* (May-June 1928).

(2) If the train consumes w watt-hours per tonne-kilometre, if the battery weighs q tons per kw.-hour recoverable on discharge and if the train weighs μ times the weight of the battery, a distance in kilometres given by $\frac{1\,000}{wq\mu}$ can be run before the battery needs recharging.

This range may in practice be taken as between 50 to 100 and 200 km. (31 to 62 and 124 miles).

The batteries are ill adapted to sudden calls, for their efficiency falls off rapidly when the rate of discharge is increased. The capacity for discharge in 1 hour does not exceed 60 % of the efficiency at the 3-hour rate.

In 2 hours one obtains 80 % of the 3-hour efficiency. Also, the voltage falls off towards the end of the discharge.

CHAPTER III.

Standardisation of rolling stock on electrified secondary railways.

Standardisation of the rolling stock of public railway companies presents such advantages that it is almost needless to dwell upon it :

— Simplification of design and construction.
— Economy in spares and in the manufacture of new material.
— Interchangeability of motor vehicles on different systems.
— Possibility of reinforcing, in case of war, the stock on one system with stock borrowed from other systems.
— Simplification of instruction of staff.

The only consideration which tends to limit standardisation results from the clog on progress which might be the consequence thereof, and the difficulty of correcting a basic error committed through a hasty or inadequately considered decision.

The above advantages are only found to a much less degree in the case of secondary systems. It is not necessary to stress this point. However, there would be a definite benefit to limit the number of frequencies and voltages used on the contract line; in standardising, in a certain measure, the collector gear, and in reducing as much as possible the number of types of parts used in the construction both of the fixed plant and rolling stock.

Consequently, this standardisation is rather a matter for the manufacturers of material than for the operating companies or inspection departments of the various States. It should result from exchanges of views between the manufacturers concerned at meetings of the professional associations, at which the manufacturers and users meet.

SECOND PART.

Conditions rendering possible the use of electric traction on secondary lines.

From the technical point of view there is nothing to limit the use of electric traction on secondary railway lines. Small locomotives have already been built of considerable power for small gauge mine and factory lines, and also it has been found possible, particularly for working trains of ore, to construct more powerful engines for metre gauge track.

On lines with heavy gradients, electric traction enables the proportion of the adhesive weight to the total weight of the train to be greatly increased, for example by using motor brakes carrying useful load, or, in the case of passenger trains, by using a greater number of motor-coaches in the trains. In the same way, the requirements as to the braking of the trains on heavy grades are more easily met by electric traction, as electric braking, with or without regeneration (1), is safer than the steam traction with counter pressure working.

The adoption of electric traction is therefore only governed by considerations of an economic order.

Case of new lines.

As we have already indicated above, it is especially necessary to deal with the particular case of new lines separately, as in this case by using electric traction great economies can be effected in hilly country in the cost of construction of the permanent way, by adopting steeper gradients and sharper curves than can be permitted with steam. If however the goods traffic is of considerable importance, it is as well not to go too far in this direction, for we should soon arrive at an excessive reduction in the useful load hauled. Lines with heavy gradients are always more expensive to operate.

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(1) On secondary lines, the saving secured by regeneration is generally of value.

In the same order of ideas it has been proposed, particularly for the colonies, to use a very small gauge, such as 0.60 m. (1 ft. 11 5/8 in.), to reduce the cost of the permanent way. Such narrow gauges do not lend themselves to the use of engines of large power except at the cost of much complication and unusual designs (1). Apart from these special cases, it must be recognised that in general, and particularly in ordinary country, nothing less than the metre gauge should be used, nor easy gradients on independent formation with comparatively heavy rails and rolling stock or large loading gauge. Lines incapable of earning sufficient return on the capital required to cover the above conditions as a rule ought not to be built at all. It is none the less true that electric traction gives railway builders fresh opportunities, and widens the radius of action of secondary lines. In spite of the crisis prevailing generally in railway transport, in the future secondary lines especially in hilly country, will still be constructed whenever the construction of a road and the introduction of an automobile service are not a more economical solution, after taking account of all the elements of the question. In particular,the wear of the roads by automobiles, and the disadvantage in the case of many countries of having to buy abroad large quantitties of petrol and rubber, must be seriously taken into consideration in this connection.

To sum up, the adoption of electric traction for a new line does not involve the scrapping of material still in good condition, and makes it possible to expend on the electrical equipment of the lines the money saved on the construction of the permanent way. The additional costs to be paid off over and above the cost of the aerial overhead line is then very small. Economies in operation are certain, the cost of energy in particular is nearly always less than that of the coal which would be consumed under steam traction, and the costs for staff and maintenance are generally lower.

Case of an existing steam line.

In the contrary case, where an *existing steam line* has to be electrified, it is necessary for comparison to add to the total of the existing financial charges that of the capital to be expended on the electrical equipment of the lines and the cost of the motor stock.

On local lines with light traffic only, one locomotive is generally used per

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(1) See, for example, the material used on the 0.60-m. and 0.70-cm. (1 ft. 11 5/8 in. and 3 ft. 6 in.) gauge lines in British India. The Railway Board of India uses engines of 30 to 40 tons, developing 4 500 and 6 000 kgr. (9 900 and 13 200 lb.) at the drawbar (adhesive weight 18 to 21 tons), and the Kalka-Simla Railway (in the Punjab) uses locomotives with 10 axles, 6 driving, weighing 69 tons, 49 tons of which is adhesive weight. Their maximum starting effort is 11 800 kgr. (23 800 lb.). These engines haul at 16 km. (10 miles) an hour trains of 160 tons on a line of 97 km. (60 miles) of which the terminus is 2 100 m. (6 890 feet) above sea-level. This line of 0.60-m. (1 ft. 11 5/8 in.) gauge has short gradients of 1 in 25 and radii of 37 m. (121 feet). (*Les Chemins de fer et les Tramways*, April 1929).

10 km. (6.2 miles) of line. The cost of the locomotives was therefore, in France before the war, of the order of 4 000 gold-francs per kilometre (6 400 gold-fr. per mile). The cost of electric motor-coaches was a little higher, but as their daily average mileage was 50 to 100 % above that of the steam locomotives, the charges on the capital locked up in the rolling stock was approximately the same for a given service as in the case of steam.

The electrical equipment of the lines, without feeders or sub-stations, cost before the war, on a small line, some 12 000 gold-francs per kilometre (19 300 gold-fr. per mile).

On lines with denser traffic (6 to 8 trains a day in each direction), at which point they begin to merit examination, the cost of motor-coaches might attain 8 000 gold-francs per kilometre (12 900 gold-fr. per mile), and that of the overhead line 16 000 gold-francs (25 700 gold-fr. per mile). Consequently, we see that scrapping the steam locomotives leads to an increase of about 50 % in the capital charges through the electrification of the light-traffic line considered.

In examining the possibility of electrifying a line, it is well to consider in turn the national interest and then that of the operating company. Electrification always brings about a saving of coal, even if only steam generated energy is available, but to equip the lines copper, an imported metal, has to be used. The immediate locking up in overhead lines of 500 to 1 000 kgr. of copper per kilometre (1 775 to 3 550 lb. per mile) costing 1 100 to 2 200 gold-francs (1 770 to 3 540 gold-fr.), saves, up to the end of the concession, an annual import of coal of the order of 300 to 600 gold-francs (483 to 966 gold-fr.), according to wether the energy is produced thermally or hydraulically.

In countries where there is under-production of coal, the operation is therefore generally advantageous from the national point of view even where hydro-electric energy is not available, but on one essential condition — the capital involved in the change must be remunerated. Even from the national point of view, this change cannot in fact be considered if the operating company will have to work at a loss.

It is therefore necessary to examine if the operating economies are sufficient to meet the charges at an adequate rate on the capital involved in the electrification of an existing steam line.

The reduction of train staffs, the lower cost of upkeep, the increase in passenger receipts due to a better service, favour the operation, but to a degree only possible to estimate for each particular case. In a general comparison or a preliminary these factors at first, and to place so- these factors at first, and to place solely in the balance the saving in coal and the financial charge resulting from the electrification of the lines. This way shows too great prudence, but it is impossible to act otherwise.

Independently of the very complicated investigation into the electrification of public railway lines (1),various authors have studied the question in the case of secondary lines (¹).

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(1) See the memoirs prepared on the occasion of the electrification of the Swiss Federal Railways, and the studies of Mr. Parodi on that of the large French systems (*Revue Générale des Chemins de fer*, Nos. of July 1924, April, November and December 1925; March, April, August and September 1926; January, March, April, July, August, October and November 1927; July 1928).

CHAPTER I.

Consumption of coal by steam locomotives.

The essential element to be determined in a comparison of this kind is the *relative consumption of coal and electric energy* on the railway considered.

The consumption of coal per ton hauled on secondary steam lines has only been ascertained infrequently, and it is very difficult to obtain any precise data on this subject from the companies. Certain tests were made, a few years ago, such as those carried out by Mr. Fettu, Engineer of the Compagnie des Chemins de fer départementaux. These tests showed the large proportion of parasitic consumptions, i. e. losses, waste and the like, the consumption of coal necessary to maintain boiler pressure when coasting and standing, and running light engine.

The actual consumption of the locomotives, during the fraction of the total period of service during which the engines are doing actual work in hauling the trains, often represents only a fraction — less than 2/3rds and sometimes less than half — of the total annual consumption. The relative influence of such secondary consumptions increases further as the number of trains on the line decreases (¹).

It is not without value, nevertheless, to try to calculate the consumption of energy theoretically required to replace on a given steam operated line, the consumption of a ton of coal.

Ratio of the total weight of a train to the load hauled.

We consider as the useful load, P*u*, the total weight of vehicles hauled, including that of the goods or passengers carried, the total weight of the locomotive being P_1 (in metric tons).

The maximum effort at the tread of the wheel, allowed by the adhesion, will be $f \times P_1$, f taking account both of the coefficient of adhesion and of the fraction of the total weight of the engine available for adhesion.

The ratio $\varpi = \frac{P_1 + Pu}{Pu}$ forms an essential factor in the consumption of coal or of energy per tonne-kilometre hauled. This factor depends on the *maximum gradient* on the line (fig. 1).

Taking the resistance to running on a straight and level track as r_l (or 7.5 kgr.

(¹) See the unpublished memoir of Mr. Chauveau deposited in the library of the « Société des Ingénieurs Civils de France » (1913):

— the report presented by the author in 1921 to the General Technical Assembly of the *Union des voies ferrées et des transports automobiles* de France;

— the report drawn up by the autor in collaboration with Mr. Ailleret, Bridges and Highways Engineer for the Commission on Standardisation of local railways (Ministry of Public Works, 1927). In the present report this memoir has been largely borrowed from.

(¹) For a small metre gauge engine lighting up takes 2 1/2 kgr. to 3.5 kgr. (5.5 to 7.7 lb.) of coal per ton of total weight of the locomotive. The consumption of coal per hour when standing may exceed 1.5 kgr. (3.3 lb.) per ton of total weight of the engine. A locomotive working at half-power and a speed of the order of 17 km. (10.6 miles) per hour consumes, for example, 260 gr. of coal per kilometre (0.57 lb. per mile) run and per ton of average weight of the engine.

The coal used for other purposes becomes relatively more costly the easier the gradient.

= 16.5 lb.) per tonne for the locomotive and r_w (or 5 kgr. = 11 lb.) for the cars, the condition of adhesion gives :

$$\varpi = \frac{r_l - r - 1\,000\,f}{r_l + i_{\max} - 1\,000\,f} \quad (1)$$

$i_{\max.}$ being the maximum gradient in thousandths on the line considered.

In the case of a locomotive of total adhesion, f is equal to the coefficient of adhesion and can be taken as 1/5 to 1/7, for example.

Consequently, for maximum gradients varying between 10 and 40 per thousand (1 in 100 to 25), and for a locomotive of total adhesion, ϖ will vary between 1.12 and 1.50, for example.

It is not unusual on hilly lines for the weight of the locomotive to equal as an annual average that of the cars hauled, and for ϖ to be about 2. In fact, while ϖ will never be less than the foregoing value, the load hauled will often be less, for operating reasons, than that permitted by the above condition, so that in practice, over the whole year, the ratio ϖ will be considerably higher than the theoretical figure calculated above. The importance of this factor is considerable, as regards the consumption of coal in relation to the useful load; it is not less so as regards the transport capacity of the line. Thus if the maximum gradient is 40 per thousand (1 in 25), the locomotives ordinarily used on the narrow gauge secondary systems (21 tons light, 28 tons loaded, 25 tons average) cannot haul a useful charge exceeding about 50 tons.

Average resistance of the line to the haulage of trains.

The second factor to be considered when calculating the coal consumption is the average tractive resistance of the line. This average resistance may, in practice, be expressed by means of virtual lengths, as is done, particularly, in Italy.

But it is more convenient, for the discussion which we have in view, to take the line being studied as equivalent to a certain *average equivalent gradient*, determined in such a way that the tractive work on a train on the parts of the line demanding an output of work shall be equivalent to the work developed to haul this train on the straight on this gradient.

If we take a line of a total length L, and consider a train making a trip out and home of a total length 2 L, this train will run over a series of sections of which some, l_1, l_2, will on rising gradients, and the others will be level or downhill. Amongst these last, certain of them will have a slope less than that of equilibrium (1).

On these sections, the tractive effort in kilogrammes per tonne of the total weight of the train, demanded from the locomotive to maintain a constant speed, is, like the first, given by

$$\frac{r_l(\varpi - 1) + r_w}{\varpi} + i_l$$

but i must be taken with the — sign, since it is a case of a down and not an up grade. These sections will thus be ranked in the same category as the first.

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(1) In practice, the numerical values of r_l and r take account of air resistance at the average running speeds. Under these conditions i *max.* must be corrected to take account of the extra resistance due, on the maximum gradient, to the effect of the curve if there is one at this point and, if necessary, of the air resistance.

(1) This is equal, in thousands, to the tractive resistance of the train on the straight and on the level evaluated in kgr. per tonne of its average weight, *i. e.* $\frac{r_l(\varpi - 1) + r_w}{\varpi}$

On the contrary, the sections l'_1, l'_2, the slope of which exceeds the slope of equilibrium, will be run without expenditure of work. We will neglect the regeneration possible either by coasting or by recuperation of energy in the case of electric traction, these conditions being rare on secondary lines.

For the out and return journey we shall have

$$2L = \Sigma l_1 + \Sigma l'_1 = L_1 + L'_1$$

In each section, we shall add to the value of the grade expressed in thousands and taken with its sign the extra resistance to traction expressed in kilogrammes per tonne and corresponding to the curves and to the air resistance if necessary. A section of constant slope will be slip up into several sub-sections if it presents parts in curves of different radius.

The effort at the tread of the driving wheels, related to each tonne of load hauled, will be in each section such as l_1 (¹):

$$F_1 = r_1(\varpi - 1) + r_w + \varpi i_1 \quad . \ . \ (2)$$

Work expended in traction.

The effective work at the tread of the driving wheels, related to the same unit, will be in kilogrammetres $F_1 \ l_1 \ 10^3$; in horse power-hours

$$\mathfrak{T}_1 = \frac{F_1 l_1 10^3}{270\ 000} = \frac{F_1 l_1}{270} \quad . \ . \ . \ (3)$$

in kilowatt-hours $0.736 \ \mathfrak{T}_1$.

The effective power N_1 at the tread of the wheels, developed in order to cover the section at the speed V_1 in kilometres per hour,

$\left(\text{or } \frac{V_1}{3 \ 6} \text{ in m./sec.}\right)$ will be in H.P

$$N_1 = \frac{\mathfrak{T}_1}{\frac{l_1}{v_1}} = \frac{V_1 F_1}{270}$$

and in kilowatt-hours $0.736 \ N_1$.

For steam locomotives, we know (or should know) the mechanical efficiency ρ_{v_1} at the rate of speed and effort corresponding to the section l_1, and the consumption of coal per indicated H. P.-hour c.

The theoretical consumption of coal to cover the section l_1 under these conditions will then be, in kilogrammes of coal per tonne of load hauled :

$$\frac{c l_1}{270 \rho_{v_1}} [r_l \varpi - 1) + r_w + \varpi i_1].$$

For a double journey of total length 2 L the consumption of coal per tonne of load hauled will thus be :

$$\left.\begin{matrix} \dfrac{c}{270} [r_l(\varpi - 1) + r_w] \Sigma \dfrac{l_1}{\rho_{v_1}} \\ + \dfrac{c\omega}{270} \Sigma \dfrac{l_1 i_1}{\rho_{v_1}} \end{matrix}\right\} \ . \ . \ (4)$$

The value of the mechanical efficiency ρ_{v_1} differing in the various sections, the exact calculation must be made section by section, and the results totalised.

But if it be admitted as a first approximation that the average mechanical efficiency of the locomotives is approximately the same, and equal ρ_v at the values practically utilised on the various sections, we can put

$$i_{av.} = \frac{\Sigma l_1 i_1}{L_1}$$

(¹) In reality, F_1 must take account of the air resistance, which is a function of the speed and of the loading gauge sectional area. But at the low speeds used in practice this extra resistance may be incorporated in the coefficients rl and rw, or, better, in the resistance due to the grade; they may even sometimes be neglected.

and *the consumption of coal per tonne-kilometre* hauled on the entire double journey will be

$$C = \frac{cL_1}{270\rho_v \times 2L}[r_l(\varpi - 1) + r_w + \varpi i_{av}] \quad (5)$$

CHAPTER II.

Expenditure of electrical energy for the haulage of trains, and possible fuel economies.

If we are considering an electric locomotive, and if we represent by ρ_e the average efficiency, or the ratio of the energy delivered to the bow, to the effective work at the tread of the driving wheels, we shall have, *in kilowatt-hours per tonne hauled.*

$$W = \frac{0.736\,L_1}{270\rho_e \times 2L}[r_l(\varpi - 1) + r_w + \varpi i_{av.}] \quad (6)$$

Admitting normal values for the resistances r_l and r_w, say 7.5 and 5 kgr., for example, we arrive at a theoretical consumption of energy in watt-hours per tonne-kilometre of total weight of train given by

$$\frac{13.5 + 2.7\,i_{av.}}{\rho_e}$$

while the *Commission des Grands Réseaux* gave a formula equivalent to

$$\frac{17 + 2.7\,i_{av.}}{\rho_e}$$

In both cases starting is neglected, although in addition $\frac{1.7}{\rho_e}$ watt-hours per tonne are used per start.

The ratio $\lambda = \frac{c}{w}$ between the consumption of coal of the steam train and the consumption of energy of the electric train measured at the locomotive collector bow is therefore, if we relate these consumptions to the tonne-kilometre hauled:

$$\lambda = c\frac{\rho_e}{\rho_v} \times \frac{1}{0.736} = 1.359 \times \frac{\rho_e}{\rho_v} \times c \quad (7)$$

c is of the order of 1.350 kgr.

In a general way the comparison thus favours traction by steam locomotives (1).

In the case of a geared electric locomotive, the efficiency curve presents the well-known form. For steam locomotives we have unfortunately no analogous data available. In his study already cited, Mr. Moreau admitted a mechanical efficiency ρ_v of the order of 0.78.

For the same service on a given line, if locomotives are used in both cases, the ratio λ is theoretically independent of the coefficient ϖ and consequently of the maximum gradient and of the coefficient

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(1) The hypotheses we have made are in effect the following :

The resistance due to curves and the resistance of the air to the real speed of the train in each section are incorporated in the value of the running resistance evaluated in kilogrammes per tonne, or in the resistance due to the gradient, which is more convenient.

We neglect the power taken in starting and the regeneration of energy by braking or running free.

It is supposed that the locomotive behaves as a hauled vehicle of resistance greater than that of the cars. This resistance is presumed to be the same for electric and steam locomotives. In the calculation of the mechanical efficiency (ρ_e or ρ_v) there is counted as effective power that developed on the shaft of the driving axles.

It is assumed that the efficiency of the steam locomotive, like that of the electric locomotive, is independent of the product (effort and speed) and an average value is attributed thereto.

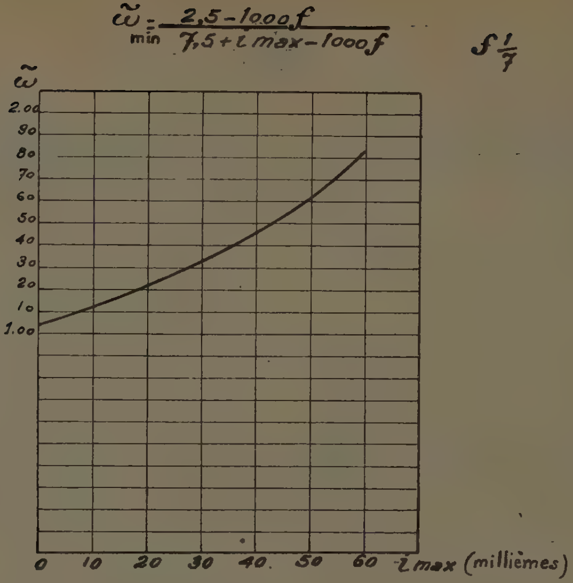

Fig. 1. — Value of ϖ as a function of the maximum gradient.

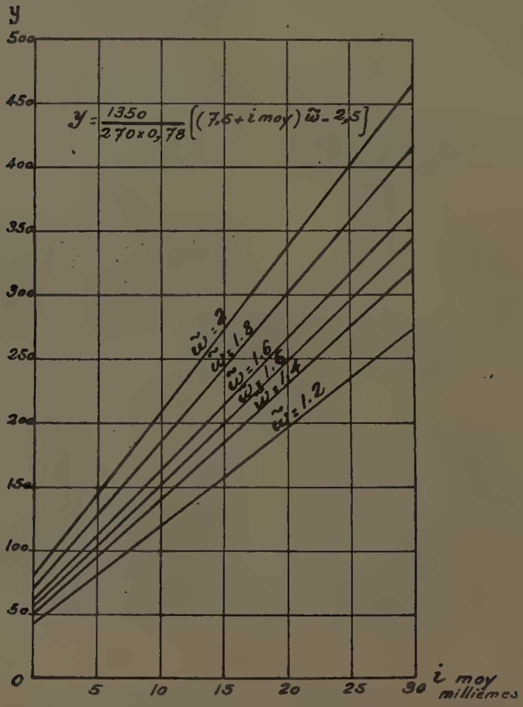

Fig. 2. — Coal consumption as a function of ϖ and of i_{av}.

Explanation of French terms: i_{moy}, millièmes = i_{av}, thousandths.

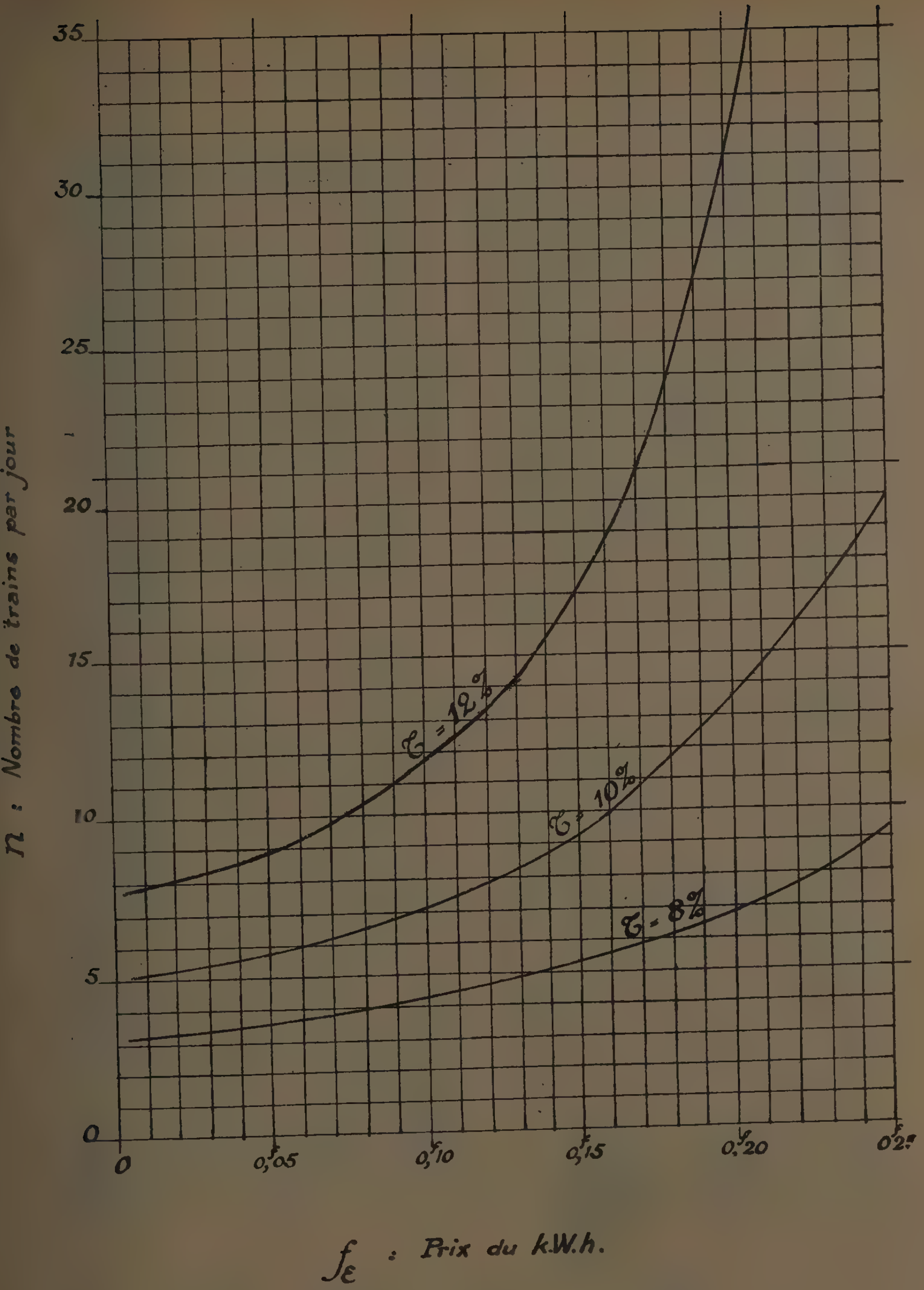

Fig. 3. — Number of trains necessary for financial equilibrium.

Explanation of French terms : Nombre de trains par jour = Number of trains per day. — Prix du k. w. h. = Cost of the kilowatt-hour.

of adhesion (¹), also of the average gradient.

It only depends on the coal consumption per H. P. indicated in the case of steam and of the ratio of the efficiencies $\frac{\rho^e}{\rho^v}$. The ratio λ would thus be in the vicinity of 2, for c is of the order of 1.350 kgr. ρ_e and ρ_v are in the neighbourhood of 0.85 and 0.78 respectively.

But the consumption of coal or of energy per tonne-kilometre hauled increases rapidly with ϖ and i_{av}, *i. e.* with the value of $i_{max.}$ and $i_{av.}$, so that the total saving realised for a given traffic increases with the difficulty of the profile (fig. 2) when electricity is substituted for steam.

The difference is accentuated in practice, because on level lines gradients can only rarely be descended by gravity, which increases in the case of steam the ratio $\frac{L_1}{2L}$.

To compare the two systems with precision, it is necessary in practice to take account of the losses in the overhead line, and if necessary in the sub-stations.

In the case of steam, parasitic losses must be taken into account, these being considerable.

We may admit in practice 5 to 10 % loss in the overhead line, 5 to 15 % and sometimes 20 % in the sub-stations, depending on whether continuous or alternating current is used and whether rectifiers or converters are employed. The best efficiency corresponds to high tension continuous current with rectifiers. Finally, the lighting of the trains, and heating, if any, etc., may represent an expenditure of the order of 5 %.

We thus arrive at an overall efficiency, from the alternating high tension current entering the sub-stations to the collector of the train, of the order of 0.65 to 0.75.

In the case of steam locomotives, we may assume $c = 1.35$ kgr. per indicated H. P., and $\rho_v = 0.78$. But the parasitic consumption is considerable, and increases by 50 to 100 % the theoretical consumption on small lines.

It can then be said that *at the collector of the train*, in the case of locomotives, 1 kilowatt-hour replaces about 2 kgr. (4.4 lb.) of coal *the parasitic consumption being neglected, or 3 kgr. (6.6 lb.) at least and sometimes 4 kgr. (8.8 lb.) if it is taken into account.*

In the case of the 3-phase high tension *entering the sub-stations*, 1 kilowatt-hour replaces 2 to 3 kgr. (4.4 to 6.6 lb.) of coal, according to the extent of the parasitic consumption, the consumptions always being related to the tonne-kilometre hauled.

If the electric traction utilises motor vehicles, the consumption must logically be related to the tonne-kilometre of useful load transported (goods or passengers).

(¹) The case is not the same if the electric service is worked by motor-coaches, the effective loading of which counts in the adhesive weight. It is then logical to compare the consumptions per tonne-kilometre of useful load transported. If the load hauled Pu comprises 2/3 of useful load, and if the adhesive weight comprises rPl of useful load, this is increased in the ratio

$$\frac{0.66\,Pu + rPl}{0.66\,Pu} \quad \text{or} \quad \frac{0.66 + r(\varpi - 1)}{0.66}$$

or

$$1 + 1.5\,r(\varpi - 1).$$

For example for

$r = 1/3$ et $\varpi = 1.5$ on a $1 + 0.5 \times 0.5 = 1.25$
$\varpi = 2.0$ on a $1 + 0.5 \times 1 = 1.50.$

The value of λ related this time to the tonne-kilometre of useful load transported can therefore increase by 25 % to 50 %, all other conditions supposed to be the same, which favours electric traction by motor cars or motor vans.

1 kilowatt-hour at the train collector then replaces 2.5 to 3 kgr. (5.5 to 6.6 lb.) of coal.

1 kilowatt-hour at the entry into the sub-stations replaces 3 to 4 kgr. (6.6 to 8.8 lb.) of coal.

These approximate figures are only given here as an idea of what may be expected.

In the latter case, however, the ratio λ increases, all the conditions being supposed equal, with ϖ, *i. e.* it is higher for the lines of difficult profile. The ratio λ related to the *useful load transported* becomes in fact :

$$\lambda' = \lambda\,[1 + 1.5r(\varpi - 1)]$$

admitting that the tare of the cars is equal to half their useful load. (Note on page 510).

The consumption of coal of the thermal power stations being of the order of 1.5 kgr. per kilowatt-hour measured at the sub-stations, electrification always conduces to an economy of coal, even if all the energy used is of steam origin.

With trains comprising a load hauled of 50 t., for example, each pair of trains daily gives 100 tkm. hauled per kilometre of line, and according to whether there are three to 12 pairs of trains the circulation per kilometre operated will thus attain 300 to 1 200 tkm. per day, and the consumption of coal will be from 10 to 100 t. per kilometre operated per annum (1).

These figures give an idea of the order of value of the gross savings realisable in fuel. For coal at p francs per kilogramme, on a line consuming K kgr. of coal per train-kilometre with a service of n pairs of trains per day, if the kw.-h. costs f_e francs, the saving achieved, per kilometre operated, will be

$$730n\left(p - \frac{f_e}{\lambda}\right)K.$$

It is effective if $f_e < \lambda p$.

This condition is always realised when hydraulic energy is available at a moderate price, or current coming from a main line already electrified (1).

But in order that the electrification may be advantageous from the financial point of view, the economy must be sufficient to cover the capital charge involved.

CHAPTER III.

Comparison of the gross savings in fuel with the financial charges involved in electrification.

Appendix No. 1 briefly recapitulates the bases of the calculation of the overhead line and of the sub-stations in the simple case of a single-line installation, with continuous current, sectionalised between the sub-stations, and assuming that there is only one train at a time in each half section, which corresponds to the case of frequent services, and with the light trains of the most common secondary lines. We arrive in practice at this conclusion, that the cost of the over-

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(1) The consumption being from 100 to 300 gr. per tonne-kilometre hauled, it will be seen that the consumption per kilometre operated per annum may vary between 11 and 130 t.

On the other hand, the locomotives on metre-gauge departmental lines consume in practice 5 to 10 kgr. of coal per kilometre run, which represents per annum and per kilometre of track 11 to 90 t. of coal.

(1) For example,

	Gold-fr.		
if $p =$	0.02	0.03	0.04
for $\lambda = 2$	$f_e < 0.04$	0.06	0.08
$\lambda = 3$	$f_e < 0.06$	0.09	0.12
$\lambda = 4$	$f_e < 0.08$	0.12	0.16

head line and its supports may be represented by (1) $\alpha + \beta n \mathfrak{T}$.

If we take as a basis for the cost of energy the cost per kilowatt-hour leaving the sub-stations, and admit that the cost of the rolling stock is not higher in the case of electric traction (case of a line to be constructed), if we again neglect at the outset the other sources of economy secured in operation by electric traction, we see that the saving in coal will balance the capital charges if we have :

$$730\,\mathrm{K}n\left(p - \frac{f_{\varepsilon}}{\lambda}\right) = (\alpha + \beta n)\mathfrak{T}$$

whence

$$n = \frac{\alpha}{\frac{730}{\mathfrak{T}}\,\mathrm{K}\left(p - \frac{f_{\varepsilon}}{\lambda}\right) - \beta}.$$

If we wished to take account of extra charges to cover the difference in cost between the two sorts of rolling stock, or the acquisition of new rolling stock (case of a line to be electrified) it would suffice to modify the values of the coefficients α and β.

To fix our ideas, we may say that in France before the war the cost in gold-francs per kilometre of overhead line (without sub-stations or rolling stock) was, for a secondary metre-gauge line, of the order of $8\,000 + 250\,n$.

The purchase of motor coaches to replace the old steam stock loaded the initial establishment charges with an extra of the order of $1\,000\,n$ francs per kilometre.

As a total, and in this case, $8\,000 + 1\,000\,n$.

We should thus have had :

in the case of a new line $\alpha = 8\,000$ and $\beta = 250$.

in the case of an existing line to be electrified $\alpha = 8\,000$ and $\beta = 1\,250$.

The minimum number of pairs of trains necessary to ensure financial equilibrium might then attain, to give an idea (fig. 3):

in the case of a new line

for $\mathrm{K} = 10$ kgr. $p = 0.035$ fr.

$f_{\varepsilon} = 0$ fr. 07 $\lambda = 2.5$

$$n = \frac{8\,000}{\frac{51}{\mathfrak{T}} - 250}$$

say for $\mathfrak{T} = 0.06$ $n = 13$

and for $\mathfrak{T} = 0.10$ $n = 32$

and in the case of an existing line to be electrified :

$$n = \frac{8\,000}{\frac{51}{\mathfrak{T}} - 1\,250}$$

so that in order that the number of trains may not be infinite one would have to have $\mathfrak{T} \leqslant 0.041$.

The value of $\mathfrak{T}$ differs according to the country and the situation of the money market. It is, in general, higher than before the war. In France, it may be taken that $\mathfrak{T}$ has risen from 0.06 to 0.10, and that it has a tendency to come down again.

These few indications, based, however, on hypotheses which bear hardly on electric traction, show that except in the case of new lines, energy at a low price and dear coal, it would be illusory to count on the operation being a paying one, if one did not take into account an economy in operation or an increase of revenue as a result of electric traction (1).

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(1) α and β are numerical coefficients of which the first depends above all on the cost of the supports, and the second on the cost of copper. $\mathfrak{T}$ is the rate of interest, sinking fund and renewal on the fixed installations.

THIRD PART.

Examination of some applications of electric traction.

The questionnaire drawn up in collaboration with our Spanish colleagues, Messrs. José-Maria Garcia-Lomas and Rivera, was sent by the Permanent Commission to 133 companies members of the International Railway Congress Association.

Out of this total 59 Administrations replied, 45 negatively, but few of them have secondary lines in the sense defined in the questionnaire and already electrified. Some others have supplied information which has been useful in the preparation of this report, on their present steam operation.

We particularly thank the companies mentioned below, who have kindly sent us reports which can really be made use of and also the Yugoslav State Railways, and the Oxelösund-Flen-Västmanlands Company, who have supplied interesting information on their steam traction.

The secondary lines which can be electrified, and consequently the replies received can be divided into the following :

1. Lines in mountainous country :

with relatively heavy traffic : Rhætian Railways; Le Fayet-Chamonix (P. L. M.);

with medium or light traffic : three companies belonging to the French Midi Railway.

2. Open country suburban or interurban lines :

with heavy traffic : North of Milan and Belgian Light Railway Company;

with light traffic : Jura Light Railway Company.

Except for the Rhætian, the North of Milan and part of the Belgian Light Railways, which form separate railway companies, the other lines are feeders of the main railway lines.

From the technical point of view, the Rhætian Railways utilise *single-phase* 11 000-volt, low frequency (16-2/3 period) current.

The North of Milan Railways use *continuous high tension current* (3 000 volts), the Jura Light Railways *continuous current* at 1 500 volts; the other companies use *continuous low tension current* (600 to 900 volts).

The two first own locomotives and motor coaches; the other have no locomotives.

The report has been drawn up upon the data supplied by the above administrations, the main figures being summarised below.

CHAPTER I.

Continuous current equipments.

I. — Belgian National Light Railway Company.

This Company has built a secondary railway system (1) 4 511 km. (2 803 miles) long, all metre gauge [except for 53 km. (33 miles) of standard gauge], and operates 4 241 km. (2 635 miles), the remainder being worked by five operating companies.

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(1) The most easily effected saving is to do away with one man per train. If the commercial speed is V in kilometres per hour, this reduction of staff saves $\frac{1}{V}$ employee-hours per train-kilometre. If the hourly wage is 1 gold-franc, for example, we shall save $\frac{1}{V}$ gold-franc per train-kilometre.

Reckoning on a commercial speed of 20 km. per hour on a small line, terminal stops included, the saving will be 0.05 gold-fr. per train-kilometre, or 1/7th. of the cost of the coal. The conditions will thus be the same as if the cost of coal were 14 % higher.

(1) The Belgian main line system has 4 722 km. (2 934 miles) of track. The tramways (6 towns) extend to 465 km. (289 miles).

Of this total, 581 km. (361 miles) are worked electrically, or by both steam and electricity (the goods trains being hauled by steam locomotives).

Hitherto, only 600-volt continuous current has been used, but the use of current at 1 200 volts is contemplated. The single-phase system, tried before the war, has been abandoned.

The Belgian National Light Railway Company has sent us a very valuable note. This Company is responsible to the State for serving the whole Belgian territory, which its system covers with a close network, throughout agricultural and industrial districts, containing 8 millions of inhabitants spread over an area of 3 million hectares (7.4 million acres).

The Company which is under the control of the State, in particular as regards tariffs, enjoys a relative monopoly comprising a preferential right as regards new concessions. The capital is found by the State, the provinces, the communes and a few private individuals.

There are 169 lines in operation, 137 of which are operated directly by the Company and are in general linked with the main line system, and sometimes with the urban tramways.

Competition from automobile transport is intense, and the main remedy tried is the electrification of the best sections threatened, and by accelerating and improving the service. The present revenue per kilometre is about 35 000 Belgian francs (56 300 fr. per mile) on the steam lines, and 160 000 Belgian francs (257 500 fr. per mile) on the electrified lines. Half these amounts are from passenger traffic. By quintupling the traffic, the electrification of certain sections has resulted in the receipts being quadrupled, with a greater profit.

On the electric lines, multiple unit motor coaches are used. Steam traction is retained for goods working when the traffic is heavy.

The system is fairly level, the gradients rarely attain 1 in 17, but the radius of curves is as small as 18 m. (59 1/2 feet). The gauge of the track is 1 metre (3 ft. 3 3/8 in.). The maximum speed is 30 km. (18.6 miles) per hour.

The steam locomotives weigh 15 to 30 tons loaded, their power is 83 H. P. The consumption of coal varies between 5 and 10 kgr. per train-kilometre (17.75 to 35.50 lb. per train-mile) (one half being parasitic consumption).

On the steam operated part of the system the train-kilometre cost 6.50 Belgian fr. (10.46 fr. per train-mile) in 1928, half of which is for traction charges.

The electric lines, owing to their dissemination, take current from local supply authorities.

Before the war, the single phase (A. E. G.) system was abandoned, to revert to 600-volt continuous current; the 1 200-volt system is being considered, but the question of interchangeability of stock is an obstacle to its adoption.

H. T. energy is supplied to the substations in the form of three-phase current at voltages between 5 000 and 15 000, and at 50 cycles. In addition to 4 old central stations which belong to it, the Company uses 24 sub-stations, 7 with motor-generator sets (150 to 500 kw.), 16 with converters (300 to 1 000 kw.), and 1 with Siemens rectifier (300 kw.). The average efficiency varies from 0.76 to 0.92 according to the type. The consumption is about 30 million kw.-h. per annum.

The kw.-h purchased according to a formula with two factors, costs from 0.40 to 0.50 Belgian francs as H. T. a. c.

The energy is fed to the overhead line by underground feeders of 200 to 400 mm^2 (0.31 to 0.62 sq. inch) and overhead feeders of 50 to 100 mm^2 (0.0775 to 0.155 sq. inch). It returns to the sub-stations by return feeders of 400 mm^2 (0.62 sq. inch).

The voltage is 550 to 600 volts leaving sub-stations, 520 to 550 volts at the end of the feeders, 375 to 500 volts at the trains. The overhead line is usually of the two-wire type, 80 mm^2 (0.124 sq. inch) on metal or concrete poles.

The tendency is to adopt the catenary suspension, which is not appreciably dearer.

The company, which has in service 829 locomotives for steam service, possesses 657 motor coaches with two motors of 35 H. P. (preferably self ventilating).

The types of carriages are standardised, and are all fitted with electro-pneumatic Pieper brake. Large 80-seat bogie cars with 4 motors are about to be put in service.

The cost of electrification are shown by the following figures :

Per kilometre (per mile) of single track	*Belgian francs*
Total cost, rolling stock included . .	500 000 (804 660)
Cost per sub-station	300 000 to 800 000)
Overhead line on Mannesmann poles, without feeders. .	115 000 (185 000)
Overhead line on Grey joints	95 000 (152 885)
2-axle motor coaches, 2 motors.	250 000 (402 330)
4-axle motor coaches, 4 motors.	400 000 643 725)
Telephonic protection.	8 000 (12 874)

The total energy per train-kilometre, leaving the sub-stations, is 0.8 to 2 kw.-h. (1.29 to 3.2 kw.-h. per train-mile). Entering the sub-stations, it amounts to 25 to 80 w.-h. per tonne-kilometre (41 to 130 w.-h. per Engl. ton-mile) of total weight of train.

After 100 000 km. (62 100 miles) running, the motor coaches return to the central shops for overhaul. The armatures are rewound as a rule after 200 000 km. (124 000 miles) and the field coils after 400 000 km. (248 000 miles).

The Company's plant is very extensive.

II. — Jura System of the General Light Railway Company.

This important Company operates in the French Jura a steam system 141 km. (87.6 miles) long and two electric lines of a total length of 52 km. (32.3 miles).

The steam locomotives, 18 tons light and 23 tons loaded, with 3 coupled axles, tractive effort 3 950 kgr. (8 690 lb.), correspond to a standard type used in France on the departmental lines. They cost before the war 32 000 gold-fr., consumed 8.5 kgr. of coal per train-kilometre (13.68 lb. per train-mile). The traction costs at present are 0.662 gold-fr. (1.065 gold-fr. per train-mile), as follows :

Fuel	0.320 (0.515)	gold-fr.
Driving staff . . .	0.165 (0.266)	—
Maintenance staff.	0.089 (0.143)	—

Repair material. .	0.068 (0.109)	—
Lubrication	0.020 (0.032)	—
	0.662 (1.065) gold-fr.	

The passenger carriages are of the bogie type (30 seats, 8.5 tons), or of the 2-axle type (18 seats, 4.5 tons), and the wagons carry 10 tons with a tare of 3.5 to 4.8 tons.

The electrification of the two lines operated by electric traction, authorised by a law of 1924, when these lines were already under construction, was finished in 1927. The electrification was due to the desire of the Department to increase comfort and speed.

The maximum gradients attain 40 per thousand (1 in 25), the minimum radius is 100 m. (5 chains); the track is laid with 26-kgr. (52.4 lb. per yard) rails. The 26-seat motor coaches weigh light 24 tons and the 30-seat bogie trailers 8.8 tons.

The former have 2 bogies and 4 motors.

The catenary line comprises a steel bearer cable of 22 mm² (0.034 sq. inch) and a copper contact wire of 68 mm² (0.105 sq. inch) reinforced by a feeder of 33 or 84 mm² (0.051 or 0.130 sq. inch). It is divided into sections at each station.

Current is supplied at 1 500 volts continuous by a single sub-station serving a radius of 20 to 25 km. (12.4 to 15.5 miles) [T. system with the sub-station at the point of intersection of the line]. There are two 300-kw. units, one being a spare. They each comprise two converters in series.

The motors of the coaches work at 750 volts. The current necessary for the auxiliary services is supplied by a small rotary set (operation of contactors etc.).

The cost per kw.-h. is at present 0.067 gold-fr., and the consumption per train-km. (33.8 t. total weight) is 3.2 kw.-h. (5.15 kw.-h. per train mile) at the entry into the sub-station. The consumption is 65 w.-h. per t.-km. (1.06 w.-h. per Engl. ton-mile) of the total weight of the train (metered on arrival at the coaches).

The sub-station is said to have cost only 32 000 gold-fr., which figure seems low. The catenary line (constructed when copper was 1.60 gold-fr. per kgr. (3.53 gold-fr. per lb.) cost 45 360 fr. at that time or 9 000 gold-fr. per km. (14 485 gold-fr. per mile). It is carried on concrete poles spaced at 51 m. (167 feet) maximum on the straight. The motor-coaches cost 43 600 gold-fr.

All these figures, which relate to a small line with light trains and infrequent service (2 to 4 pairs of trains per day) agree closely with those given by us earlier (page 511).

The price of *traction* in 1928 was 0.469 gold-fr. per train-kilometre (0.755 gold-fr. per train-mile) (¹):

III. — Fayet-Chamonix Railway.

This is a real secondary railway, on an independent formation, fed by continuous current at 600 volts by an insulated third conductor rail.

The installation dates from 1897, and is well known. From the information obligingly communicated by the Paris, Lyons & Mediterranean Company, the following data only need be given here: length of the line 37 km. (23 miles),

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(¹)

	Gold-fr.
Energy	0.214 (0.344)
Sub-station	0.022 (0.035)
Overhead line	0.037 (0.060)
Driving staff.	0.073 (0.117)
Maintenance of motor coaches	0.012 (0.019)
Lubrication	0.023 (0.037)
Total (without general charges, track, station service, etc.)	0.469 (0.755)

gauge 1 metre, maximum gradient 90 per thousand (1 in 11), minimum radius 150 m. (7 1/2 chains).

The line starts from the 580-m. (1903 feet) level, and reaches 1 384 m. (4 540 feet).

The line is a tourist line, with heavy traffic, operated in summer with 22 pairs of passenger trains, one mail and one goods; it is partly closed in winter.

Operated by simple adhesion, the line has no locomotives, and almost all the vehicles are motor-driven (73 passenger cars out of 96, and 86 wagons out of 89), of the total adhesion type (2 motor axles). Maximum speed 35 km. (21.7 miles per hour). Commercial speed (without the stops at the terminus) 18 km. (11.2 miles per hour). Average weight of a train 150 tons (max. 230).

The energy is supplied in the form of continuous current at 600 volts, and is taken from a third rail fed at 4 points by two hydro-electric stations and 2 substations. One of the stations has six continuous current sets of 300 kw., the other 4 similar sets, and two turbo-alternators of 1 200 kw., 25 periods, feeding two substations each equipped with two 500-kw. converters, and a battery of 1 200 ampere-hours, 600 volts.

The rails are divided into sections at 4 points, and the conductivity is reinforced in various sections by a bonded copper conductor. The central rail on which the clip brake acts, increases the conductivity of the return circuit.

The motor-coach stock is of a type specially designed by the engineers of the Paris, Lyons & Mediterranean Company, and is well known. The motor coaches have 38 to 44 seats, and weigh loaded an average of 23 tons. They cost at the present time 48 000 gold-fr. (half for the truck). The motor wagons carry 10 tons.

The consumption of the trains, per tonne-kilometre of total weight, is about 85 w.-h. (exclusive of heating).

The central depot has a foreman and two assistants, twenty-two tradesmen, five inspectors, three to thirteen washers, two or three labourers. The motor-coaches are examined every 20 000 km. (12 400 miles), and the motor brakes every 10 000 km. (6 210 miles) (1).

The Fayet-Chamonix line is an example of a location chosen with the maximum admissible gradient for simple adhesion. Thanks to the precautions taken and to the low running speed, there have been no accidents.

IV. — North of Milan Railways.
3 000 - volt continuous current.

The standard gauge system of the North of Milan Railways has a length of 255 km. (158.4 miles) and serves an industrial region of much natural beauty which attracts tourists. Having obtained a new concession from the State in 1925, the Company proceeded with important permanent way works (doing away with level crossings, doubling the track), and with the electrification of a section of 40 km. (25 miles) Milan-Saronno and Milan-Meda), also the installation of the block system, etc.

When the partial electrification of the system was decided upon, the traffic was already very heavy, a few branches or cross lines having a service of only six pairs of trains a day, whereas on the main line, Milan-Saronno-Laveno, the traffic was between fifty and fifteen pairs of trains.

It was decided to provide for a 15-minute suburban service, capable of being increased in the future to a 10-minute service, the result being the adoption of multiple-unit trains. Three-phase was set aside a priori, and single-phase was likewise rejected, for it would have led to cumbrous equipments, double the weight of continuous current equipment, and further the greater inertia of the single-phase rotors would have considerably increased the consumption of energy, seeing the fast service with frequent stops which was contemplated.

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(1) (See *Revue Générale des Chemins de fer*, August 1900, November 1901, April 1902, November 1908).

Mr. Nissim, Engineer, reporter to the Technical Meeting of Genoa (1928), in a very interesting article on the North of Milan system, from which we borrow the following data, states that the Swiss Federal Railways' single phase motor coaches with 72 seats, 90 km. (55 miles) per hour, 780 H. P., weigh 101 kgr. (222 lb.) per H. P. and 1 095 kgr. (2 409 lb.) per passenger, while three known types of high tension continuous current stock give :

MOTOR COACHES.	Paris-Orleans. 1 500 volts.	Illinois Central. 1 500 volts.	North of Milan. 3 000 volts.
Seats	86	84	89
Tare	65 tons.	65 tons.	53 tons.
Weight per H. P.	66 kgr. (145 lb.)	65 kgr. (143 lb.)	71.6 kgr. (157.5 lb.)
Weight per passenger	755 kgr. (1 661 lb.)	755 kgr. (1 661 lb.)	595 kgr. (1 309 lb.)

The sub-station is situated at 7 km. (4.35 miles) to the north of Milan, and will contain four mercury vapour rectifiers of 2 000 kw., three of which are now installed. It receives three-phase current at 23 000 volts, 42 periods. The rectifiers can support an overload of 50 % for half an hour and 100 % for five minutes. Each of them is connected to the busbars by two extra high speed circuit breakers (1 per pole). The electrified part of the system comprises two lines with a common trunk section Milan-Bovisa of 4 km. (2.5 miles), presenting beyond this point two branches of 17 and 19 km. (10.6 and 11.8 miles) respectively (Bovisa-Saronno and Bovisa-Meda), so that the longest distance to be fed does not exceed 14 km. (8.7 miles).

The overhead line is on the simple catenary system with anti-swing arrangements and standard bracket posts, the brackets pivoting in the supports, and arms carrying the anchoring devices for the tensioning adjustment . The carrier cable and the contact wire are each of copper of 80 mm² (0.124 sq. inch). The poles are of steel tube.

The rail bonds are electrically welded.

The rolling stock consists of motor coaches 20 m. (65 ft. 7 in.) long, weighing 53 tons light, 62 tons fully loaded, with two bogies and four motors of 185 H. P. hourly rating (140 H. P. continuous). Maximum speed 100 km. (62 miles) per hour.

The stopping trains consist of a motor coach and a trailer with driving compartment, between which there can be inserted one or two ordinary trailers, likewise of the bogie type.

The motors are coupled in pairs in series, and the multiple unit equipment with electropneumatic control and the so-called « dead man's handle » device, makes it possible to operate with only one man on the motor coach. The traction circuit is protected by an extra high speed circuit breaker, double break, with a damping resistance between the two. The compressor motor is fed at 3 000 volts, and the same applies to the heating circuit. The control and lighting circuits are taken from a 36-volt battery charged by a dynamo chain-driven from one of the axles.

The goods service is handled by locomotives with 4 driving axles distributed over two bogies, with 4 motors of 345 H. P. hourly rating, under 1 350 volts at the speed of 40 km. (25 miles) an hour.

The lines have been opened to operation too recently for precise data to be furnished as to the cost of electrification and operating results.

I. — Rhætian Railways.

This Administration has replied very fully to our questionnaire, and has added to its reply an interesting technical description of its installations. These constitute an interesting example of a secondary system of the heavy traffic type, with a hilly profile, and operated by single phase low frequency current.

The total length of the system is 277 km. (172 miles), entirely of metre gauge. It is situated in the Canton of Grisons, and serves a large number of well known seasonal resorts. We find on the system maximum gradients of 35 and even 45 per thousand (1 in 29 and in 22). The minimum radius of the curves is 100 m. (5 chains). On one of the lines there are several spiral tunnels, and a long tunnel of 5.9 km. (3.7 miles). The operation of the Rhætian Railways is guaranteed against the competition of road transport by the prohibition of all traffic of this kind in the mountainous region; but private motor cars take away a considerable number of travellers from the railway.

The Engadine line was electrified as an experiment on its construction (1911-13); the remainder of the system was at first worked by steam, then electrified between 1918 and 1922 by reason of the high price of coal, the lack of this fuel during the war, the difficulty of the route and the frequent tunnels. In this region, hydro-electric energy was available on good terms.

The majority of the trains are mixed, but there are express trains not conveying goods, and also, some trains carrying goods only.

For the whole of the system, the traffic corresponds to 13.4 pairs of trains for passengers, and 1.9 pairs of goods trains, as a daily average.

Electric traction has enabled the speed and weight of the trains to be increased.

The Rhætian Railways only use locomotives, to the exclusion of motor coaches. The tonnages hauled run from 250 t. (246 Engl. tons) on the level at a speed of 50 km. (31 miles) per hour, to 150 t. (148 Engl. tons) on the maximum 45/1 000 (1 in 22) gradient and at the reduced speed of 30 km. (18.6 miles) per hour.

There are usually three employees per train, and a brakesman is added when there are more than 10 axles on the train.

Each electric locomotive replaces two steam locomotives, and the speed is 10 % higher. The electrical material comprises 189 passenger cars, 65 on bogies (carrying 35 to 68 passengers), the other have two axles and seat 18 to 44. There are 39 goods vans and 630 wagons, of which only a few are bogies.

The bogie wagons carry 25 tons, and the others 10 to 15 tons.

It is obvious from these figures that the stock of the Rhætian Railways can cope with considerable traffic.

The track is laid with Vignoles rails of 27 kgr. (54.4 lb. per yard) on iron sleep-

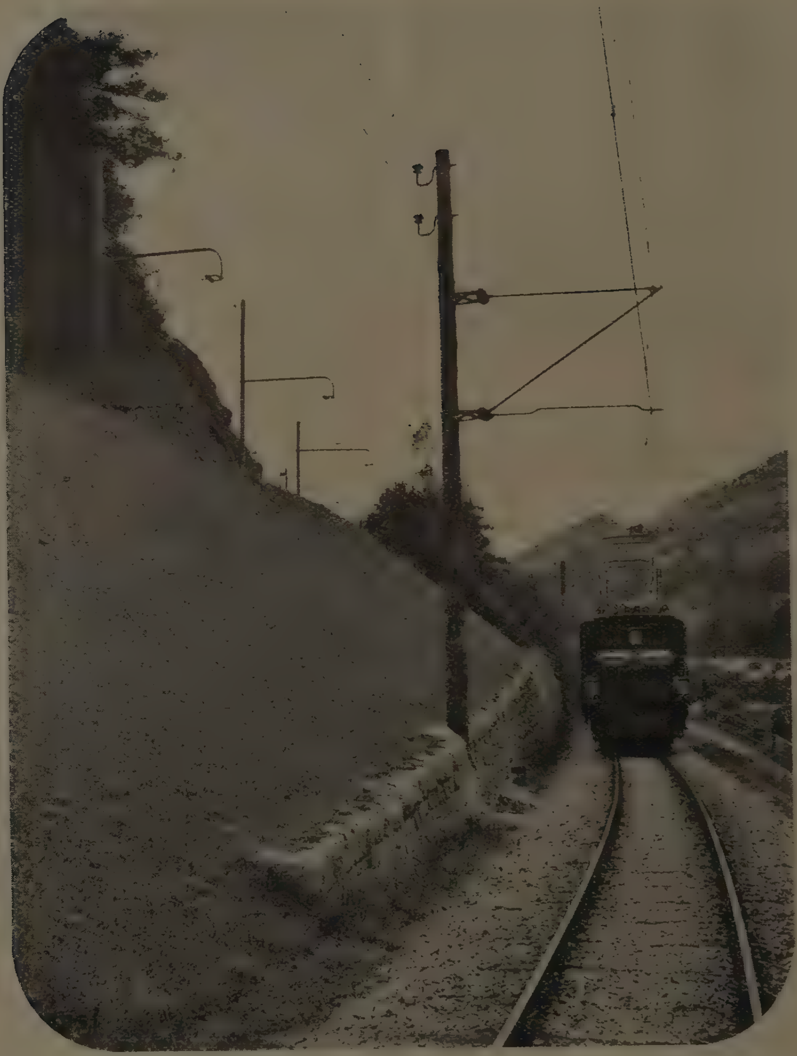

Fig. 4. — A line of the Rhætian Railways.

ers, and can carry axle weights up to 11 tons.

Single phase 11 000-volt current is used for traction, at a frequency of 16-2/3 periods per second.

The voltage of 15 000 utilised by the Federal Railways was not adopted because of the limited loading gauge available in the tunnels. Power is supplied by two private companies, feeding the system at three points.

One of these supplies is given in single phase current direct, the others utilise sub-stations containing motor-generator sets each comprising an asynchronous three phase motor coupled on the one hand to a continuous current generator of 1 000 kw. and a single phase alternator of 750 kw. continuous rating—maximum 1 300 k.-v.-amperes. The set is, in addition, provided with a flywheel of 20 tons, the kinetic energy of which is 15 000 kgm².

These sets serve as buffer sets, utilising also a battery of accumulators of a capacity of 1 250 ampere-hours.

This installation, dating from 1912, is principally utilised today for voltage regulation, the machines serving as phase advancers, for the conversion of the current and the upkeep of the batteries constitutes a heavy charge.

The other supplier furnishes the single phase current by means of a converter set (asynchronous motor — three phase-alternator — single phase) of a continuous rating of 1 700 k.-v.-a. (maximum 3 400 k.-v.-a).

The power installed totals 7 900 kw. (continuous rating) with 13 000 k.-v.-a. (maximum output), and in 1927 the peak load on the whole system reached 6 800 kw.

The last converter group mentioned above permits the absorption of the energy generated by the descent of the trains when no trains are coming up, and to this end the turbo-alternator of the generating station is provided with a braking nozzle.

The contact line is a simple catenary.

The use of the auxiliary bearer wire has been tried on a part of the Engadine lines.

The posts are, in general, of impregnated fir, but they have had to be replaced at the end of six years, and they are at present being replaced by iron poles. Their maximum spacing is 60 m. (197 feet) on the straight.

The contact wire is of copper (85 or 70 mm² = 0.131 or 0.108 sq. inch section), the bearer wire of galvanised steel (40 mm² = 0.062 sq. inch); counterweights every 1 500 m. (4 920 feet) automatically regulate the tension of the wire.

The doubly-insulated contact line has alongside it a feeder line of 50 mm² (0.0775 sq. inch) to facilitate sectionalisation in case of accident. Sectionaling is arranged for on each side of each station. The catenary suspension has been maintained in the tunnels by bringing the points of suspension as near as 20 m. (65 ft. 7 in.).

The electrical bonding of the rails is effected by means of galvanised iron wires 6 mm. (15/64 inch) in diameter. The return feeders are very short.

The rolling stock comprises thirty locomotives, the mechanical part of which was supplied by the Société Suisse pour la Construction de Machines, Winterthur, and the electrical part either by Brown-Boveri or by Oerlikon. These machines are of the 1-B-1 — 1-D and C. C. types.

Their weight varies from 37 to 68 tons. The weight of motors is 1 to 2 tons, with an hourly rating of 300 to 600 H. P. and a continuous rating of 200 to 500 H. P.

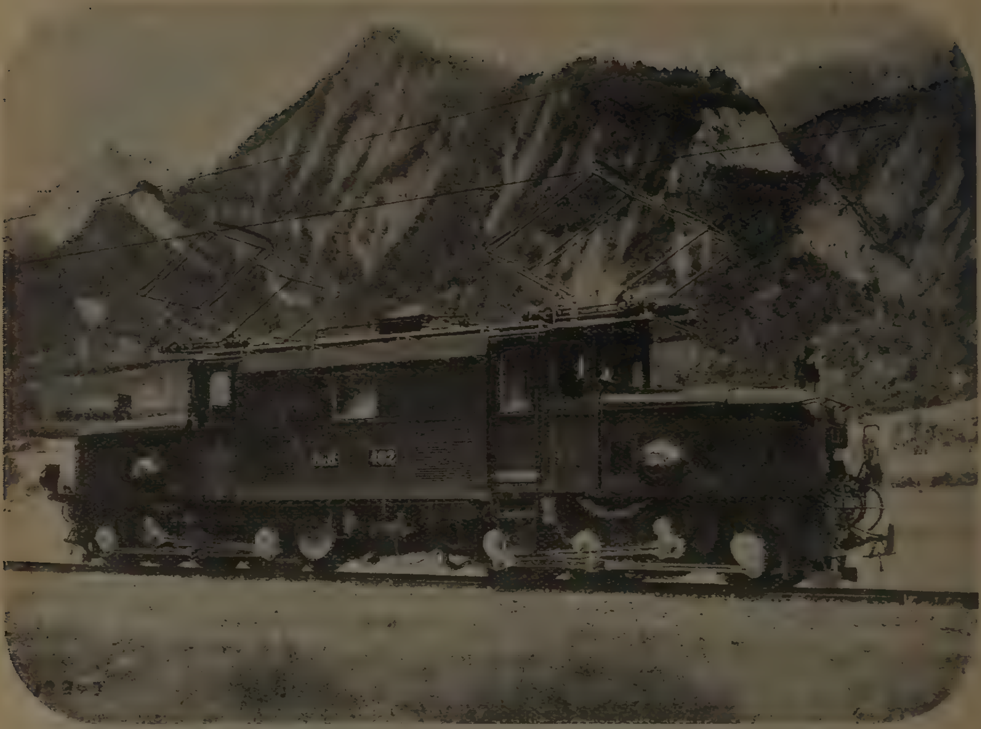

Fig. 5. — Brown-Boveri C.C. type locomotive of the Rhætian Railways.

The speed is 28 to 30 km. (17.4 to 18.6 miles) per hour for a tractive effort varying from 2 800 to 9 700 kgr. (6 172 to 21 384 lb.).

The last model adopted, represented by fifteen machines, is of the new C. C. type (Brown-Boveri and Oerlikon). Each machine has two single-phase motors, series excitation, with collector, with compensating winding and shunted commutation poles. There are also resistances connected between the sections and the rotor collector; these motors have 12 poles cooled by fan, connected in parallel, controlled by means of a transformer with multiple tappings, and permitting of braking by working as a continuous current generator on resistances with independent exciters.

The locomotives are illustrated in figures 5 to 7. They are, as will be seen, mounted on bogies with 3 coupled axles, driven by a large connecting rod actuated by an intermediate shaft.

The usual disadvantages of single phase current with regard to telegraph and tele-

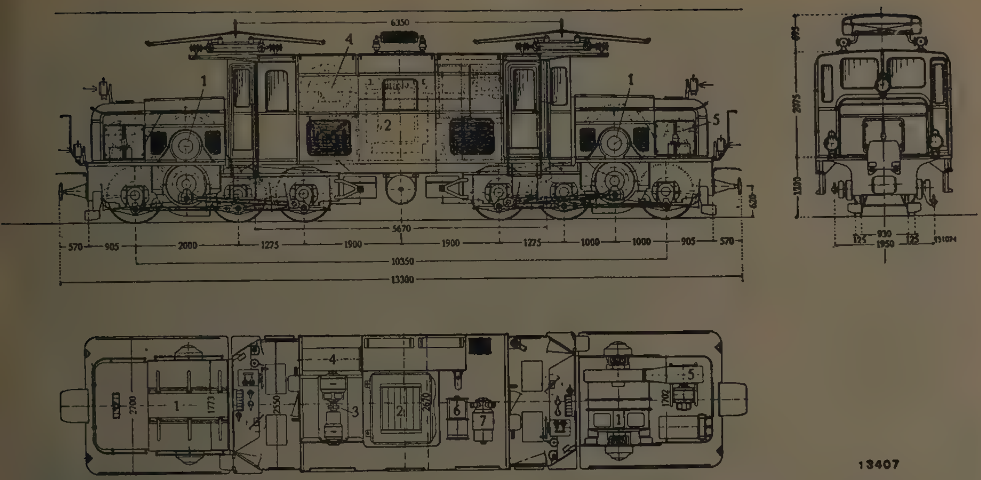

Fig. 6. — Brown-Boveri C. C. type locomotive of the Rhætian Railway. — Elevation and plan.

phone lines have been eliminated by removing the latter from the railway, and doing away with earth return in the case of telegraph lines.

Automatic electrically controlled signals are installed at the entry to the stations.

Cost of electrification.

The Company has had the courtesy to communicate to us the following particulars :

The Engadine lines (62 km. = 38.5 miles of single track electrified in 1911-1912) cost, as regards the overhead line, without the sub-station : 26 670 gold-fr. per km. (42 920 gold-fr. per mile).

The Albula lines (215 km. = 134 miles of single track equipped from 1918-1922) cost 27 560 gold-fr. per km. (44 350 gold-fr. per mile).

The increase in the cost of everything and the incorporation in the outlay of the modification of the low tension lines have been in great part compensated for by the simplification of the constructional arrangements for the line.

The fourteen locomotives delivered before the war seem to have cost on an average 100 000 gold-fr. each.

The sixteen locomotives since received have cost 365 000 gold-fr. each.

Leaving aside the cost of the sub-stations and also that of the rolling stock properly so-called, excluding the locomotives, we find, all complementary works included, an electrification cost coming out at 51 000 gold-fr. per km. (82 000 gold-fr. per mile) of single track for the lines electrified before the war, and 90 500 gold-fr. per km. (145 600 gold-fr. per mile) for the lines electrified after the war, carrying a heavier traffic.

With regard to the operating expenses, the Rhætian Railways consume 8.45 kw.-h. per train-km. (13.60 kw.-h. per train-mile), which corresponds to 59.5 w.-h. per tkm. (97.3 w.-h. per Engl.ton-mile) of total weight of train.

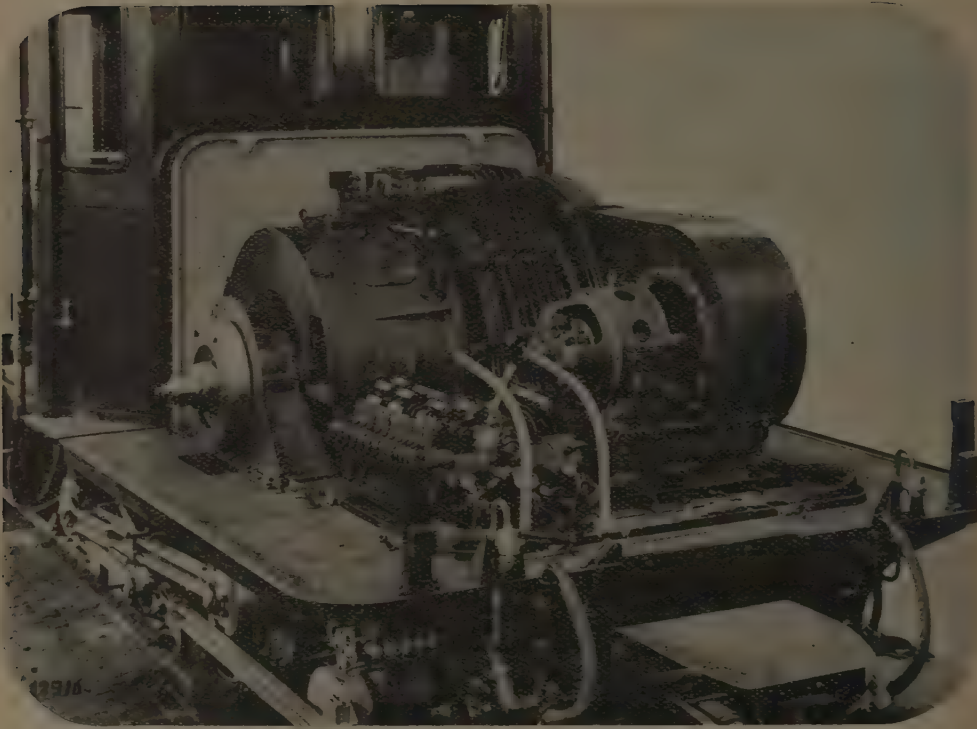

Fig. 7. — One of the two single phase traction motors of the C. C. type locomotive.

The cost of upkeep of the overhead line comes to 354 gold-fr. per km. (570 gold-fr. per mile) of single track per annum.

In 1927, the cost of traction was made up of :

	Gold francs per train-km.	Gold francs per train-mile
Driving staff	0.339	0.546
Maintenance and repairs	0.200	0.321
Lubrication	0.011	0.018
Total . . .	0.550	0.885

The annual distance run per locomotive per annum has reached 63 000 km. (39 150 miles), or an average of 200 km. (124 miles) per day. The Company expects a reduction in the cost of upkeep of the lines, by reason of the progressive substitution of metal poles for the original wooden poles, and by the substitution of locomotives of the new types for the old pre-war machines.

The Company has also supplied valuable particulars on maintenance matters.

Two separate depots each look after half of the system, the total length of which is 277 km. (172 miles). At each of these two depots, for maintaining the overhead line, there is a gang of four men using a special wagon driven by a motor-car engine; a fifth man is required when the poles have to be renewed.

The rolling stock is repaired at main workshops (¹).

The workshop is fully equipped; cranes and hoists are provided for lifting the locomotives.

The railway system has in addition, four locomotive depots, at two of which running repairs are done (²).

Heavy repairs involving complete stripping down of the locomotives, are carried out every 120 000 km. (74 600 miles) for the old machines, and every 150 000 to 250 000 km. (93 200 to 155 300 miles) for the more recent, which corresponds to nearly three years of service.

Between heavy repairs the tires have to be returned.

The collector brushes are examined about every week for the repulsion motors, and every two to four weeks for the series motors.

Every month the switchgear is gone over, and every three months the high tension cut out.

The collectors of the repulsion motors need to be trued up once a year, without however it being necessary to take them down.

For the series motors, the collector is only trued up during the heavy repair of the machine.

The passenger cars are heated by means of electric radiators.

II. — Railways of the Camargue.

This Company operates a local system of metre gauge lines, of a total length of 124 km. (77 miles), two lines of which, of 32 and 16 km. (20 and 10 miles) respectively, are operated electrically, using single phase current, 25 periods, 6 000 to 6 600 volts.

The Company is unusually situated, for it operates in the only region in France where there is still to be found a power distribution system on a large scale at 25 periods.

This fact has made it possible for the single phase current necessary for traction purposes to be taken directly from one of the three phases of the supplier's distribution. Thus no sub-station is required, and the system is fed at a single point (Arles), the feed radius not exceeding, we think, about 40 km. (25 miles).

The electrified lines were previously worked by steam, and electrification enabled the number of trains to be increased from three to five pairs per day, four for passengers and one for goods, the last-named being worked by steam locomotives.

Electrification has also permitted the time for the run to be reduced by about 30 %, and has increased the number of passengers carried by 25 % in two years.

The operating company expected, amongst others benefits the elimination of locomotive feed water, a trouble some

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(¹) This workshop has :
1 shop manager,
9 technical employees or foremen,
84 workmen.
This staff maintains :
27 electric locomotives,
8 old steam engines,
189 passenger cars,
669 goods wagons.

(²) The corresponding staff includes :
2 depot managers,
5 technical employees,
38 qualified artisans,
32 cleaners.
To the depots are attached 41 drivers and 29 assistant drivers who occasionally assist in the maintenance work.

necessity in a region where the waters are of very bad quality, the possibility of penetrating easily into the interior of the towns of Nîmes and Arles, and finally greater comfort (electric lighting and heating) was expected to facilitate the development of passenger traffic.

The Company decided it must use equipment of low cost using light rails not exceeding 20 kgr. (40.3 lb. per yard) in weight, and a single 50-mm² (0.0775 sq. inch) trolley wire.

These conditions were the more readily met by the particularly level character of the system, the maximum gradient being 12/1 000 (1 in 83), and the easy location with curves of not less than 200-m. (10 chains) radius.

The catenary line is carried by concrete posts not more than 51 m. (167 feet) apart; the State telegraph and telephone lines have been moved to avoid any induction effects. The distribution line of the Company is carried on the poles used for the overhead line and is protected by well proven devices which have given every satisfaction.

The rail motor coaches are bogie stock weighing 27 tons and equipped with 4 motors of 75-H. P. hourly rating, each weighing 1 550 kgr. (3 420 lb.), the total weight of the complete equipment being 12 tons, including 2.5 tons for the autotransformer. The average weight of the trains is 70 to 80 tons, the commercial speed 33 km. (20.5 miles) per hour, the speed on the level 45 km. (28 miles) per hour. The maximum weight of the trains has at times attained 120 tons. It will be seen that the motor coach weighs from one-third to one-quarter the total weight of the train. The power at starting is 180 to 200 kw., and when running 100 to 150 kw. The power factor is between 0.5 to 0.9 under various running conditions.

No feeder has been necessary to reinforce the single overhead wire.

The monthly average of the power factor is 0.74 to 0.77. The total efficiency at the incoming switchboard terminals is 0.60 to 0.65. The consumption in watt-hours per tonne-kilometre of total weight of train at the point of current supply is 34 watt-hours in summer an 42 watt-hours in winter (55.6 and 68.7 w.-h. per Engl. ton-mile respectively), because of the electric heating and lighting, which corresponds to a consumption of 2.4 and 2.6 kw.-h. per train-kilometre (1.5 and 1.6 kw.-h. per train-mile).

The Camargue system constitutes a very interesting application of 25-period alternating current, under particularly economical conditions, although we have no exact information as to the cost of construction.

For two motor coaches in daily service, the Company possesses, six, two in reserve, one under running repairs, one under general overhaul or repair.

The system has been operating since 1920, and after eight years' service the transformers have not been repaired, the gears not replaced, and the wear of the rotating parts has been insignificant so far.

In 1927, the traction costs, properly so called, amounted to 0.30 gold-fr. per electric train-km. as against 0.90 fr. per steam train-km. (0.481 and 1.443 gold-fr. per train-mile respectively) being made up as follows :

	Per train-km.	Per train-mile.
Train staff	0.07	0.112
Electric power . . .	0.06	0.096
Lubrication.	0.01	0.016
Upkeep of motors and overhead line.	0.16	0.257
	0.30	0.481

The above particulars have been taken from a report by Mr. Bertrand, Engineer in Chief of the Company, presented to the last Technical Meeting of the *Union Française des voies ferrées d'intérêt local.*

In this study, Mr. Bertrand furnishes interesting comparative data on the results obtained in the seven French local light railway systems using single phase current.

Two of these systems had advised the reporter that the system has disadvantages. The Omnibus & Tramways of Lyons, who had adopted equipments on the mixed single-phase and continuous system, found them unsatisfactory, and have had to abandon the system.

The same was the case with the Provence Railways, which used single phase motor coaches.

The other operators declared themselves as being satisfied; however, the Libournais Tramways report a low overall efficiency, and the Belfort Territory Railways report defects in the motor rotors.

The Haute-Vienne Departmental lines have also had trouble and have had to strengthen their equipments. It is well to point out that amongst the companies which have retained the monophase system, two have a relatively heavy service, corresponding to 25 or 30 trains a day, and three an infrequent service, corresponding to 4 pairs of trains.

The power factor reported by the different operators varies from 0.60 to 0.80.

CONCLUSIONS.

Although the limits of the present study do not permit of the detailed treatment which would be necessary for an exhaustive analysis of the results obtained in practice, the replies received permit us, when considered along with the theoretical aspects set forth at the beginning, to examine some applications which we may regard as typical, and to draw from this examination some conclusions of a fairly general character.

We thus find that the technical progress made since the war has brought to considerable perfection the two main systems of traction applicable to the secondary lines, *i. e.*: H. T. continuous current (1 500 to 3 000 volts), and single-phase 16.66 or 25 periods at the pressure of 10 000 to 12 000 volts (in exceptional cases 6 000 to 15 000 volts). The voltages which can be resorted to with the former system, still too low, in our opinion, for the main lines, are sufficient for the secondary lines, and the lower powers called for on these do not give rise to the difficulties resulting from the heavy currents to be handled which are present with heavy traction service at 1 500 volts continuous current, for example.

Finally, mercury arc rectifiers, wonderfully well adapted to the production of continuous current at 3 000 volts and over, have come along to widen the field of application of this system, and to reduce the financial drawbacks (lower voltage than with single phase) by the possibility of multiplying sub-stations.

On the other hand, the trouble experienced in certain countries with single phase when first introduced are now forgotten, the equipments having been suitably strengthened and the motors improved. This system permits of economical installations being provided when the system to be operated is very extensive, above all if traction current ready transformed is not available.

The construction of overhead lines has made progress, while being simplified, the influence of the traction current on the telephone and telegraph lines is better prevented today, and is generally not serious in the case of continuous H. T. current.

It may thus be said that the Companies from the technical point of view have only the difficulty of making the selection.

If the system is not extensive, or is divided up, it is easier to obtain supplies of continuous current for traction, as the production of single phase low frequency current necessitates expensive rotary substations.

The choice will therefore depend most often on the nature of the current feeding the main line with which junction has to be made, if this line is already equipped.

With regard to the use of accumulators, which are of very great interest in the frequent case of light-traffic lines, this is still in the experimental stage, and their use remains limited to lines of very easy gradient with very light trains.

If we now look at the economic side of the problem, the question is much more delicate than when we are on technical ground. In fact, the secondary lines differ from each other on many points, but present in general the common feature that the traffic is only light. That is to say, the saving in coal to be expected from the general use of electric traction on such lines is in general small in absolute value. The saving resulting therefrom is but rarely sufficient to warrant the cost of electrically equipping the lines and of purchasing new rolling stock. This is a great obstacle to the use of electric traction on these lines. Electrification is only possible in cases in which the technical advantages of this method of traction dictate its use (difficult gradients, new lines, etc.), or when electric energy is available at a low price while coal is dear. In most cases only when there is relatively heavy traffic, requiring at least 10 pairs of trains per day, for example, can electrification be a paying proposition, even for a new line.

For an existing line, it will be necessary to have a still heavier traffic. This is what justifies applications such as that of the North of Milan Railways, the Rhætian Railways, etc., where a line already operated by steam has been electrified with success, the line having a heavy traffic. It is the same in certain cases where road motor car competition, for example, can only be fought effectively by electrification.

We have sought in this note not to give figures purporting to serve as an absolute criterion, but to show in a general way in what sense and in what measure the various factors act, on which depends the solution of the economic and financial problem imposed by electrification.

This solution is facilitated in countries which, in order to reduce their importation of mineral fuels, subsidise, as France and Italy have done, electrification, by legislative arrangements favourable to its financing.

But in order that the necessary capital may be found in future, it will further be necessary for legislation to ensure to the electrified lines a certain guarantee against the competition, at present unrestrained, of public automobile transport.

APPENDIX I.

Calculation, in a concrete case, of the consumption of coal and of energy, and of the cost of the overhead line.

Consumption of coal and of energy.

We may predetermine approximately the coal consumption of locomotives.

Draw up, according to the longitudinal profile of the line, the plan of the line and the curve of the speeds as a function of the tractive effort, a table which gives, on totalisation of the corresponding columns :

$$\Sigma \frac{l_1 i_1}{\rho_1} \text{ and } \Sigma \frac{l_1}{\rho_{r_1}}.$$

Calculate, from the value of the maximum gradient, the average coefficient ϖ taking account of the fact that the useful load will not exceed, as an annual average, two-thirds, for example, of the maximum possible.

The formula (5) then gives the theoretical fuel consumption per tonne-kilometre hauled. It must be increased by the relative percentage for the coal used for other purposes (1).

Calculate in a similar manner, in the case of electric traction, the consumption of energy per tonne-kilometre hauled, using formula (6).

It is to be increased by the value corresponding to starting and auxiliary consumption, losses in the line and in the sub-stations.

Calculation of the overhead line.

First select the equipment of the trains. To this end determine the equivalent average imaginary gradient, and choose according to the weight of the typical train a motor supplying on the average and maximum gradients the desired values of effort and of speed. The corresponding powers must be, as a first approximation, those of the motor on continuous rating and hourly rating respectively.

We will suppose, for the sake of simplicity, that continuous current has been adopted. We choose a value for the line voltage and for the motor voltage where several motors are coupled in series.

The motor being thus determined, draw up a precise table giving for each section of the line considered the amperage per motor and the total current taken by the locomotive, also the energy consumption when running and when starting. Calculations can then be made with accuracy, we know for each section the amperage I and the running time t_1.

Calculate the loss of energy $\Sigma I_1{}^2 T_1$ by Joule effect in the line and determine:

$$I_{\text{eff.}} = \sqrt{\frac{\Sigma I_1{}^2 t_1}{T}} \quad . \; . \; . \; . \; . \; (8)$$

In order that the total of the financial charges related to the copper in the line and the value of energy lost by the Joule effect may be the minimum, it is necessary that the current density in the overhead line corresponding to I_{eff} may have an optimum value called the economic density δ.

It can easily be proved that in the case of a single track line served by sub-stations equidistant from L_x with sectionalising in the middle of the intervals, if there is only one train in each half-section, the value of δ is given by (¹):

---

(1) Speed regulation is effected in practice by throttling the steam with the regulator; the steam or coal consumption per I. H. P. depends thereon, and varies in a striking way with the skill of the driver.

$$\delta = \frac{\eta}{\sqrt{K}}.$$

We determine thus the economic section S of the overhead wire

$$S = \frac{I_{\text{eff.}}}{\delta}$$

which can, however, be appreciably reduced without much affecting the total annual outlay.

The kilometric resistance R of the line is then easy to calculate (²). It gives immediately the average and maximum voltage drops

$$\frac{L_s}{2}\,RI_{\text{av.}} \quad \text{et} \quad \frac{L_s}{2}\,RI_{\text{max.}}$$

which must not exceed, for example, a fraction ε_1 or ε_2 respectively of the voltage E leaving the sub-stations.

We also deduce therefrom spacing L to be given to the sub-stations.

$$L_s = \frac{2\varepsilon_1 E}{RI_{\text{av.}}}.$$

The capacity of the sub-stations and their operating conditions result from the foregoing.

We find readily that

$$L_s = \sqrt{\frac{2\varepsilon_1}{\rho\delta}\;\frac{I_{\text{eff.}}}{I_{\text{av.}}}\,E}$$

The spacing of the sub-stations thus grows, in the simple case considered, as the square root of the supply voltage. But, in addition, the section of copper necessary for a given average or maximum power is inversely proportional to E.

Hence the considerable advantage of high transmission voltages.

For the same service, with the hypotheses made, the annual period of utilisation is the greater the more widely spaced the sub-stations are, which conduces again to the adoption of as high a feed voltage as possible. Nevertheless, the annual utilisation period of the peak is always poor on lines with infrequent service (3 to 12 pairs of trains a day).

Knowing the section of line adopted definitely, and the voltage accepted, it is easy to determine the type of supports and the cost per kilometre of line, in which the electrical bonding of the rails is included.

This cost varies, with the traffic density, and may be represented by

$$\alpha + \beta n$$

where α and β are numerical coefficients, the first of which depends mainly on the cost of the supports, and the second on the cost of copper (weight and price per kgr.).

(¹) η is a factor of economic order, and K the number of hours during which the current circulates in the section in one year divided by 8 760.

$$\eta = \frac{1}{3}\sqrt{\frac{f_{cu}}{f_e}}\,\mathcal{T}$$

fcu being the cost in francs per kgr. of copper, and *fe* and $\mathcal{T}$ the cost per kw.-h. and the rate of interest and sinking charges on the line.

(²) As a first approximation, we may neglect the resistance of the return circuit. The average drop per kilometre in the track is of the order of 0.02 I*av.* and only takes place during running with consumption of current. It only represents a few thousandths of the feed voltage, at least in the case of light trains and infrequent service.

APPENDIX II.

Information supplied by operating undertakings.

A questionnaire drawn up in collaboration with our colleagues, Messrs. J. M. Garcia-Lomas and Rivera, was sent through the International Railway Congress Association to the undertakings forming part of the Association.

As regards the countries of Europe, which alone the present report covers, the results obtained have been as follows :

Of 133 undertakings interrogated, 59 only have replied, and amongst these 45 have indicated that they had no interesting results to communicate, 9 have replied partially to the questionnaire (such as giving certain figures concerning their operation by steam locomotives), finally 5 only have proved able to make a really useful contribution to our study.

This result need not surprise, for the members of the Association only possess few secondary lines, and electric traction is still little represented among them.

The object of the questionnaire was primarily to collect information of a general kind on the nature of the lines, the technical and commercial conditions of their operation, and the results expected from any electrification, or obtained where such a transformation had been carried out.

The questionnaire defined in continuation the technical and economic data required to be known in the case of steam and in the case of electric traction.

Finally, a supplement contained a series of questions regarding the data necessary in the comparative calculation of the consumptions of coal or energy, and, in the case of electric traction, in the calculation of the main data for the design of overhead lines, sub-stations and rolling stock, and for estimating the yield and cost of the electrification.

Replies not concerning electric traction.

The Tarn Departmental Railways (Chemins de fer Départementaux du Tarn) operate three metre-gauge lines with a maximum gradient of 40/1 000 (1 in 25), curves of 100 m. (5 chains), mixed trains of 80 tons, with three employees, locomotives of 22-28 and 18-24 tons. This undertaking is a normal one amongst the French departmental secondary railways, with an average of three pairs of trains per day. The expenditure of coal is 10 kgr. per train-kilometre (35.4 lb. per train-mile) or 23 t. per km. (36.3 Engl. tons per mile) per annum. The coal costs some 38 gold-fr. per ton, involving an expenditure for fuel of 852 gold-fr. per kilometre (1 371 gold-fr. per fr. per train-kilometre (1.390 gold-fr. per train-kilometre (0.61 gold-fr. per train-mile).

Traction alone (fuel, driving staff, repairs and maintenance) costs 0.864 gold-fr. per train-kilometre (1.390 gold-fr. per train-mile).

Electrification is not contemplated, for no increase of traffic would be expected from it. Only the elimination of one of the three train employees would be expected in that case.

The French Midi Railway Company, which has, moreover, replied to us fully regarding two small electrified systems, gives us the following information on three small secondary systems operated by branch companies (table p. 532):

Of the three systems, two were to be electrified in 1927, but the scheme has since been abandoned. The low frequency of the service easily explains this.

—		Landes Railways.	Midi Departmen Railways. (Lot-et-Garonne).	Chalosse et Béarn Steam Tramway.
Gauge of track		1.44 m. (4 ft. 8 $^3/_4$ in.)	...	1 m. (3 ft. 3 $^3/_8$ in.)
Length operated, kilometres (miles).		343 (213)	...	143 (89)
Electrification		Not contemplated, but has been.	No.	No, but has been considered.
Pairs of trains per day.		2 (mixed).	...	1.5 and 2 (mixed).
Number of employees per train		3	...	3
Maximum and average gradients (1 000ths)		25-10 to 12 (1 in 40, 1 in 100 to 1 in 83)	40 (1 in 25) (?)	40 (1 in 25) (?)
Minimum radius, metres (chains)		110 (5 $^1/_2$)	30-40 (1 $^1/_2$ to 2)	40 (?)
Train-kilometres (train-miles) run (thousands)		577 (358)	...	188 (117)
Number of locomotives existing		23	10 (1 rail car).	9
in effective service		8	5	6
Thousands of tr.-km. (of train-miles) per annum.		576 (358)	locos. 145 (90) r.-car. 25 (15.5)	...
Coal consumption in kgr. (in lb.).	per tr.-km. (per train-mile).	8.8 (31.2)	60-t. train, 13 kgr. (46.1 lb.) 50-t. train, 8 kgr. (28.4 lb.)	14.7
	per km. (per mile) of line	15 820 (56 160)	11 000 (39 050)	19 240 (68 300)
Price of fuel, gold-fr.		48	...	43
Traction costs in gold-fr. per annum and per km. (per mile) operated.	*a*) fuel.	244 (393)	70 (113)	118 (190)
	b) driving staff	75 (121)	32 (51.5)	33 (53)
	c) repairs and upkeep	80 (129)	44 (71)	80 (129)
	d) lubrication.	6.7 (10.8)	10 (16)	6.6 (10.6)
	e) sinking fund for material.	96 (loc.) (154)	...	...
	f) various	2 (3.2)	2 (3.2)	0.6 (0.96)

Finally, the French Est Railway only has one small line of standard gauge, on which run tramway-trains to the number of 30 per day, and of a length of 3.3 km. (1.7 miles) only.

We have received from England only one reply, from the London & North Eastern Railway, relative to thirteen secondary steam lines (six operated directly by the London & North Eastern) which are all tributaries of main lines, with mixed services, and in general five pairs of trains at most per day. There is no question of electrifying them, but the London & North Eastern Railway also operates directly a secondary electric line (electrified from the start), running with continuous current at 600 volts. This is a passenger tramway, giving a half-hourly service, mainly for the transport of workmen between the station and the docks (distant about 12 km. = 7.5 miles).

The Yugoslav State Railways operate 2 370 km. (1 473 miles) of secondary standard-gauge lines, and 1 830 (1 137 miles) of 0.76-m. (2 ft. 6 in.) gauge. Some of these latter are really main lines, over which express trains run. Finally, 493 km. (306 miles) of lines of 0.60-m. (1 ft. 11 5/8 in.) gauge, abandoned by the enemy, are going to be replaced by standard gauge track. Electrification is not contemplated.

The standard gauge locomotives weigh 21.7 tons, 27 tons, 35 tons and 38.5 tons. There are in all 333 engines — 245 in service and 88 under repair. The consumption of fuel varies from 65 gr. to 95 gr., and as an exception 161 gr. per tonne-kilometre (0.29 lb., 0.41 lb. and 0.72 lb. per Engl. ton-mile) (locomotive included).

Sweden.

Swedish State Railways.

Have no secondary electrified lines.

The other undertakings have not replied, or have sent negative replies.

The Oxelösund - Flen - Västmanlands alone has replied to the questionnaire, and this is a case of a very important line, 253 km. (157 miles) in length connecting the ore field of Grängesberg to the port of Oxelösund. This line, the electrification of which has been enquired into, is still operated by steam, with locomotives of 80 t. (78.7 Engl. tons) hauling trains of ore of 1 100 t. (1 082 Engl. tons) on the easy gradient of 10/1 000 (1 in 100) — 6 km. (3.7 miles). The consumption of coal is 16 kgr. per train-kilometre (57 lb. per train-mile). The traffic intensity is measured by the very high average of 1 502 800 t.-km. (goods only) per kilometre (933 240 train-miles per mile) operated.

Switzerland.

The line from Viège to Zermatt, still operated by steam, is going to be equipped with 11 000 volts singl phase. The equipment is already on order.

[656. 213]

REPORT No. 3

(Belgium, France and their Colonies)

ON THE QUESTION OF THE RELATIONS BETWEEN RAILWAYS AND SEA PORTS (SUBJECT IX FOR DISCUSSION AT THE ELEVENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION) (1) (2),

By ULYSSE LAMALLE,
Director of Operation, Belgian National Railway Company.

Fig. 1 to 34, pp. 536 to 574.

SUMMARY :

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(1) This question runs as follows: « Relations between railways and sea ports: lay-out of maritime stations; arrangement of outer and inner basins so that the most efficient lay-out of sidings may be provided for working them; operating and rate fixing methods; loading and discharging appliances. »

(2) Translated from the French.

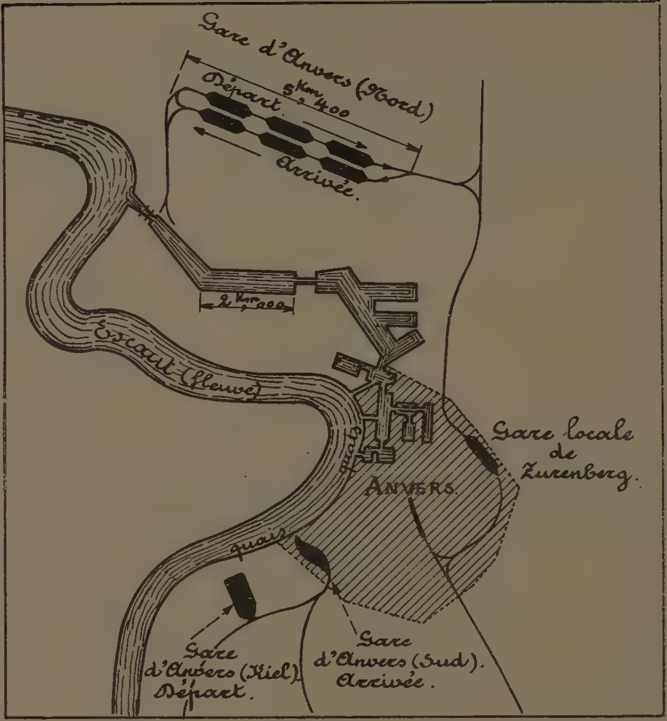


Fig. 1.

Explanation of French terms: Arrivée = Arrival. — Départ = Departure. — Gare d'Anvers (Nord) = Antwerp (North) station. — Gare locale de Zurenborg = Zurenborg local station.

In the course of our report, which deals only with Belgium and France, we shall as far as possible follow the order of the questionnaire drawn up by us in collaboration with the other reporters on Question IX.

PART I.

Harbour stations.

From the point of view of output, whether of equipment or of staff, it may be stated that it is always desirable to concentrate the whole traffic of a port in one station; but local topographical conditions or certain special reasons may lead to deviation from this principle.

It would appear *a priori* that if the site available is sufficiently large to allow of placing the station at the centre of gravity of the harbour installations, wagon journeys to the quays will be reduced to a minimum.

If, however, this arrangement is not possible, the obvious alternative will be to have the station at the head of the harbour installations in the direction of the

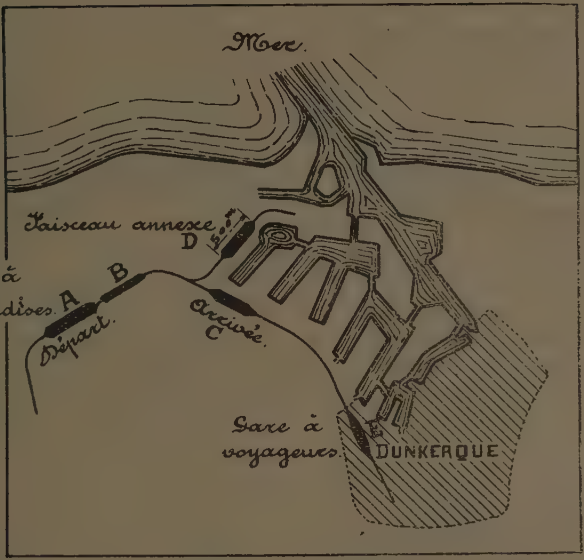


Fig. 2. — Port of Dunkirk.

Explanation of French terms: Faisceau annexe = Secondary sidings. — Gare à voyageurs = Passenger station. — Gare à marchandises = Goods station. — Mer = Sea.

interior, but it will always, in principle, be a single station.

If the port and the adjoining agglomeration are very important and in consequence cover large areas, and if, further, the harbour installations are grouped on either side of the agglomeration, e. g. on the north and south sides, it may be found advisable to have two stations serving these two groups of installations, provided that the volume of traffic is such as to allow of the formation of complete trains to and from the interior for each of the two stations.

If, on the other hand, it were decided in such a case to adhere to the principle of a single station, that station would obviously be situated on the most important and busiest side of the port.

Example. — At the port of Antwerp, figure 1, there is one station on the south side which serves a quarter of the harbour installations, and one on the north side which is intended to serve three-quarters of the quays. If there had been sufficient space available, the latter station would have been constructed on a site a little more to the east (towards Austruweel), so as to be nearer the centre of the quays.

If it is proposed to instal a single station, but the land available is insufficient for the complete realisation of this principle, there is the further alternative, where space permits, of having one station for wagons arriving from the interior and, at another spot, a second station for wagons proceeding from the quays towards the interior, that is to say there will be separate arrival and departure stations. Such is the case at Antwerp (South) and Antwerp (Kiel) (fig. 1), whereas at Antwerp (North) the arrival and departure installations are together.

At *Dunkirk*, wagons arriving at the port are received at one station (fig. 2), while wagons leaving the port for the interior are concentrated at another station, A B, but in fact these two stations are very close together.

The ports of Bordeaux, Cette and Bayonne, which are served by the French Midi Railway, have not adopted the system of the single concentration station.

* * *

It may be asked, what must be the volume of traffic to justify the construction of a harbour station distinct from the station which serves the local agglomeration.

In this report we deal only with the larger ports; consequently, as it is the maritime traffic which determines the site of the station, the installations necessary for local traffic can only be comprised within that station if it is in the vicinity of the agglomeration in question. If this is not the case, it will be necessary to provide a local station. In our opinion, the question of whether the local station may be combined with the harbour station depends more on topographical conditions than on the volume of traffic.

However this may be, it does not necessarily follow that wagons proceeding to the goods sidings of the local station will proceed there direct. We believe, on the contrary, that it may be desirable to despatch to the harbour station not only the harbour traffic, but also the through traffic and local traffic. After marshalling, the local traffic wagons will be shunted to the goods sidings of the local station.

It is in this way that in the near future the Antwerp (North) station will deal not only with the traffic of the North basins, but also with the traffic of the line from Antwerp to the frontier station at Eschen, the through traffic with Holland, the local traffic directed to the local station, Antwerp-Zurenborg, and the traffic with the Merxem agglomeration which is served by a private station.

The French Nord Railway Company is of the same opinion, *viz.* that it is not necessary to have separate stations for local traffic, through traffic and harbour traffic, so long as the limit of capacity of the sole existing station has not been reached, which limit the Nord Railway Company puts at from 3 500 to 4 000 wagons per 24 hours in the case of modern stations.

* * *

When the splitting up or marshalling of trains on arrival or before departure can be effected at different periods of the day, it is desirable, from the point of view of economic working, that the organisation of a harbour station should comprise installations common to the two traffic directions. In this case, however, the lines leading into the station should be laid in a loop so that there is only one traffic direction within the station.

When the above-mentioned operations must take place simultaneously, and the total traffic cannot be dealt with by means of a single gravity hump between the receiving and shunting sidings, it is necessary to have separate installations for arrival and departure. Examples : Antwerp (North) and Soquence (Le Havre).

When several different railway lines terminate at a given port, it is not advisable that each of them should have a separate station. For the convenience of the clientele, who only expect to deal with a single responsible organisation, and also in order to ensure the most economic conditions of working, it is preferable to establish a single station common to the different railways.

It would not seem possible to make any *a priori* distinction between the installations of a harbour station and those of an inland station, for the reason that, in a harbour station, trains arriving from the interior run on to the receiving sidings and undergo a process of shunting according to quays, which resembles the process of marshalling according to direction, and are then further shunted according to ships emplacements, which resembles the process of marshalling according to geographical destination.

Although it is true that these stations do not have to provide for the re-marshalling of transit trains, the installations are not the more simple for that, in view of the fact that they still have to provide for the transfer between arrival and departure lines of a certain number of empty wagons which, on returning from the quays, have to be re-despatched to other more or less distant quays within the port.

As for wagons proceeding from the port to the interior, they necessarily undergo the same operations as the wagons dealt with in an inland marshalling yard, *viz.* entrance into a receiving yard, shunting according to direction and geographical classification.

The French Nord Railway Company, in cases where the *export* traffic is extensive, recommends supplementing the shunting yard by special sidings for that traffic, these sidings being suitably placed in relation to the various quays.

We follow the same practice in Belgium, and we call these sidings « back-quay sidings », but in the Belgian ports they are also used for *import* traffic. They serve as accommodation sidings for loaded and empty wagons, their object being to ensure a continuous quay service.

Experience shows that port working is subject to frequent interruptions and disturbances, due either to delays in the arrival or departure of ships on account of fogs or storms, or to the displacement of traffic as a result of the suspension of work in other ports or in neighbouring countries, or to disputes between employers and employed, which disputes are more frequent in ports than anywhere else, etc. For these reasons harbour stations must be planned with a certain amplitude to allow of holding loaded or empty wagons pending the arrival of ships overdue, and of coping with unexpected interruptions, thereby preventing the difficulties experienced within the port from extending to the railway system outside.

Similarly, incidents affecting the working of the outside railways (such as derailment causing prolonged obstruction of main lines, to quote only one example) must not be allowed to interfere with work in harbour stations. These stations must be in a position to accommodate wagons which the affected lines are temporarily unable to take.

If a harbour station is to fulfil its rôle of « compensator » from this double point of view, the departure sidings C_3 towards the quays (fig. 3) and the departure sidings B_3 toward the interior, must be more extensive than would be required for normal traffic. It may be desirable, also, with the same object, to supplement the sidings B_3 by a further group of lines, B_4, to accommodate wagons awaiting departure.

Sequence of operations in harbour stations.

In the *old* installations at Antwerp these operations are performed as follows :

1. In the receiving sidings for trains arriving from the interior, the wagons are marked according to final destination, that is to say, they are marked with the number of the quay siding for which they are intended; they are further marked with the name of the consignee and the date of arrival.

2. The train is then split up, and the wagons are re-grouped according to quays; in other words, wagons intended for adjoining quays are re-marshalled in the order of the quays.

3. The groups of wagons are then run on to the back-quay sidings, where they are split up and re-grouped according to ships. In these old installations, the back-quay sidings may be regarded as a species of « auxiliary station ». We shall see below that in more recent installations they have lost this character.

4. The wagons are then run on to a line alongside the ship.

Marshalling according to hatches is effected on request in the back-quay sidings. Sometimes the marshalling is done « according to the port of destination », the loading of the ships being then affected in reverse order to the ports of call.

In the new installations at Antwerp (North), which are only partially in operation, marshalling is carried even further, for marshalling according to ship's emplacement is also carried out in the harbour station, in accordance with the plan shown in figure 3.

The station comprises two groups of three continuous sets of lines :

1st group :

— Lines C_1, for the reception of trains arriving from the interior;
— Lines C_2, for shunting according to quay groups;
— Lines C_3, for shunting according to ships' emplacements.

2nd group :

— Lines B_1, for the reception of wagons arriving from the quays;
— Lines B_2 for shunting according to direction towards the interior;
— Lines B_3, for marshalling according to geographical destination.

As will be seen from figure 3, there is sufficient space available to allow of doubling these installations, *i. e.* of providing twelve sets of lines, should the increase in the traffic of the port require it.

In the more recent installations of the port (basins and basin-canal), there is in the proximity of *each* quay-side a group of lines, known as « back-quay » lines (figs. 4 and 5), but, unlike the old installations, these groups of lines no longer have the character of « auxiliary stations », their rôle consisting essentially in the accommodation of loaded or empty wagons for the purpose of ensuring the uninterrupted feeding of the quay or goods shed lines. Only the final sorting takes place on these groups of lines, such as classification according to ship's hatches, or special classifications asked for by the stevedores (for example, classification according to ports of destination).

The type of harbour station adopted at Antwerp (North) (fig. 3), characterized by its groups of lines laid end to end, appears to us to be the most suitable type. The old Northern stations at Antwerp (Austruweel, Zurenborg), which are to be replaced entirely by the Antwerp (North) station, comprise dead-end sidings; this results in frequent shunting delays when trains enter for splitting up and when the various elements are leaving after being split up.

The new arrangement of sidings shown in figure 3 requires greater space, but it was possible to adopt it at Antwerp (North) where the space available was quite adequate. On the other hand, at the station of Antwerp (Kiel) — which is the departure station corresponding to the arrival station, Antwerp (South), for traffic from the quays along the Scheldt (fig. 1) — dead-end lines have had to be retained owing to the inadequate length of the space available.

The railway installations at *Dunkirk* (fig. 11) comprise :

1. The *harbour station* C (24 lines), which receives all empty and loaded wagons arriving at Dunkirk, with the exception of complete trains which are run directly either on to siding D, or on to the piers at the spots at which they are to be dealt with.

These wagons, after being sorted, are shunted to the appropriate sections of the port;

2. Siding D (26 lines), waiting lines and lines for the shunting of empty or loaded wagons before they are run on to the piers or quay-sides;

Siding D is in the nature of an auxiliary station where wagons are shunted according to ship or to consignee. The shunting of wagons according to ship's hatches is generally effected by the stevedores by the means which are placed at their disposal (horses, tractors or capstans);

3. The quay lines, on which take place the direct operations between ship and wagon or inversely;

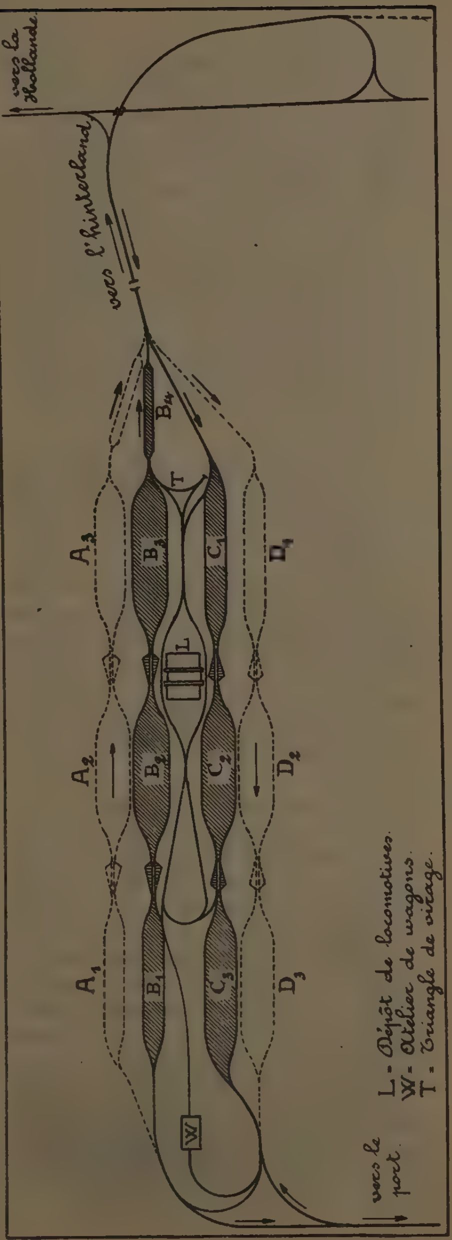


Fig. 3. — Harbour station at Antwerp-North.

Explanation of French terms, etc.: L = Locomotive depot. — W = Wagon repair shop. — T = Turning triangle. — Vers la Hollande = To Holland. — Vers le port = To the port. — Vers l'hinterland = To the interior.

4. The lines at the interior of the quay spaces to hold wagons which have to be run on to the waterside tracks, and those which have to be loaded with goods stocked on the quays or in the sheds, as for example textiles and timber;

5. *The Dunes station* (« Gare des Dunes ») A B, consisting of two quite distinct parts :

a) Shunting sidings B, with 6 lines and with a gradient for gravity shunting without the use of shunting engines. It is on to these sidings that the sets of loaded wagons proceeding from the port are run directly;

b) Splitting up and marshalling sidings A, with 22 lines, on which after splitting up, trains are marshalled for despatch to the interior.

Trains arriving at Dunkirk from the direction of Lille are no longer received via the line M N at the harbour station (station C); they run over the transition curve R_1, R_2, R_3, and thus enter directly into siding C or D, making a circuit round the departure sidings A. This procedure adds 6 km. (3.7 miles) to the length of the run.

As we have seen, sidings B serve for the reception of groups of wagons leaving the quays, which groups are shunted in sidings A, whence the trains are despatched towards Lille, using the same transition curve, R_2, R_1.

This shows that modern practice is not afraid of adding appreciably to the distance by running wagons round a wide curve, if this results in more efficient working and increased output within a station.

The Nord Railway Company points out that at Dunkirk the harbour station C and the subsidiary waiting lines D are situated at only a short distance behind the docks, thus leaving no margin for improving the relations between the port and the station.

Figure 10 shows the amplitude of the harbour station which the French State Railways propose to construct to serve the port of *Le Havre*.

Movement of unloaded wagons when re-loaded in the port.

Should they be passed back systematically through the harbour station ?

There are several cases which must be considered :

1. the unloaded wagons may be re-loaded on the spot;

2. they may be passed on directly to a neighbouring section of the same group of quays;

3. some of them may be passed on directly from one group of quays to another as required; only the wagons then remaining will be sent to the harbour station, whence they will be despatched to the interior or to the port.

In any case, the empty wagons which are to be re-loaded within the port will only pass back through the harbour station if they can thereby reach their new destination more rapidly or more easily than by being run over the quay tracks.

Despatch of wagons from the interior to the harbour station.

If wagons containing goods for export by one and the same ship are presented to the railway as a single despatch, these wagons must be run to the port in such a way that they may arrive at the quay-side together, or at least, if they are very numerous, that they may arrive there successively and without interruption and as soon as the contents of the preceding wagons have been transhipped. This is on the assumption, in principle, that all these wagons have arrived in the same train.

Economy of working, however, demands that the load of the trains shall approximate as closely as possible to the limit allowed by the maximum power of the locomotives. Hence, from this point of view, it should be admitted that any spare capacity which certain trains might have should be filled up by wagons detached from a group constituting a single despatch. In *Belgium* it is, as a general rule, forbidden to split up groups of wagons thus offered but the splitting up is tolerated when the despatching or marshalling stations have a subsequent train with which the delayed wagons can be run so as to arrive at the port in sufficient time to be brought to the quay-side simultaneously with or immediately after the wagons previously despatched. It will be seen that the principle of economy takes second place to commercial considerations.

On the *French Nord Railway* a distinction is made, as regards this question of the dividing of groups of wagons, between export and import traffic. In the case of export traffic this dividing up is forbidden so as to avoid any possibility of impeding or delaying the loading of a ship. In the case of import traffic, the conditions and rules are the same as for ordinary traffic.

On the *French State Railways* the wagons of any single consignment must not, in principle, be broken up, but where an exception is made to this rule the second batch must arrive by the following train.

As regards the ports served by the *French Midi Railway*, there is generally no restriction as regards the breaking up, whether at the despatch station or en route, of groups of wagons despatched from the interior to a port.

PART II.

CHAPTER I.

How are the shipping, commercial and railway exigencies of a port to be reconciled ?

Ports present very varying characteristics according to their geographical situation, and this is not without its effect upon their relations with the railways.

Where there is no tide, as in the Mediterranean, all that is necessary may be :

a) to level up the shore and to provide it with quays;

b) to fix the limits of future basins by constructing a protecting jetty and piers. The basins thus formed are known as « open » basins, because they are permanently open to navigation in the absence of locks. (Example : Marseilles, with its 7 open basins, established along the shore, with a depth of water of from 7 to 25 m. [23 to 82 feet], figs. 6 and 7).

Open basins may also be constructed at ports where the tide is slight. (Example : Rotterdam, with a tide variation of 1.50 m. [5 feet]). But in coastal ports, where the tidal variations are greater, the basins must be closed by means of locks in order to maintain a constant level during the period of low tide. This type of basin is known as a « tidal dock ». (Le Havre, tide 7 m. [23 feet], fig. 8; Dunkirk, 4.50 m. [14 3/4 feet], fig. 11; Ostend, 4.60 m. [15 feet]).

Ports constructed at a distance from the sea, on rivers which have a sufficient depth, are known as « inland ports » (Antwerp, at 88 km. [55 miles] from the coast, figs. 4 and 5; Hamburg, at 100 km. [62 miles]; Bordeaux, at 95 km. [59 miles], fig. 12; Rouen, at 125 km. [78 miles], etc.). In the case of certain inland ports, all that has been necessary has been to construct quays along the river banks (Rouen); in other cases, basins have been constructed in addition, though without locks, the tidal variations not being unduly high in view of the distance from the coast (Hamburg, tide 1.90 m. [6 feet]). In yet other cases a mixed system has been adopted, *viz.* the construction of free water quays along the river banks. and the construction of basins the water of which is regulated by means of locks (Antwerp, tide 4 m. [13 feet], figs. 4 and 5; Bordeaux, 1.25 m. [4 feet]).

It is to be remarked that when the traffic of a port attains a certain volume, quays constructed exclusively in free water along the river banks tend to develop in length to an extent which is not conducive to concentration of working. In such cases it may become advisable to supplement them by inner basins which, by judicious planning, may be made to afford, within a reduced area, an equal total length of quayage.

Figures 4 to 15 give plans of each of the following ports :

Antwerp, figs. 4 and 5;
Marseilles, figs. 6 and 7;
Le Havre, figs. 8, 9 and 10;
Dunkirk, fig. 11;
Bordeaux, figs. 12 and 13;
Ghent, fig. 14;
Strasburg, figs. 15 and 16.

It will be seen that the older parts of all the ports comprise more or less rectangular basins, bordered by quays, and grouped more or less suitably, though without any apparent method. In a number of cases these installations date back to the pre-railway era.

The new basins, on the other hand, are usually constructed on what is called the « darse » system, which is comprised of basins leading out of a common trunk, like the teeth of a comb; the trunk may be a river or a canal, and the basins are separated by parallel walls in the case of coastal ports, or by parallel ground spaces in the case of inland ports.

The following questions at once arise :

Which is the better arrangement : basins perpendicular to or forming an acute angle with the shore or canal on to which they are branched (fig. 17)?

What is the most suitable angle from the point of view of facility of access for the railway ?

What is the minimum width that should be adopted for the dividing walls or grounds spaces ?

What should be the maximum length of basin ?

In this connection it will be realised that it is necessary to reconcile three points of view, namely the shipping point of view, the railway point of view and the trader's point of view.

From the shipping point of view, the question of angle assumes different aspects according as the common trunk is a canal without current or a river with a single or double current.

It may be noted :

1. That, in the case of the canal, the basins are in general inclined in the direction of the entrance lock (fig. 4);

2. That, in the case of a river which has a constant current, the basins are generally inclined in the direction of the current (figs. 15 and 16); it is fair to remark that this inclination is suited to the direction of the main traffic which, both up stream and down, is to be found between the port and the river mouth. It appears, moreover, to be the most suitable from the point of view of not silting up;

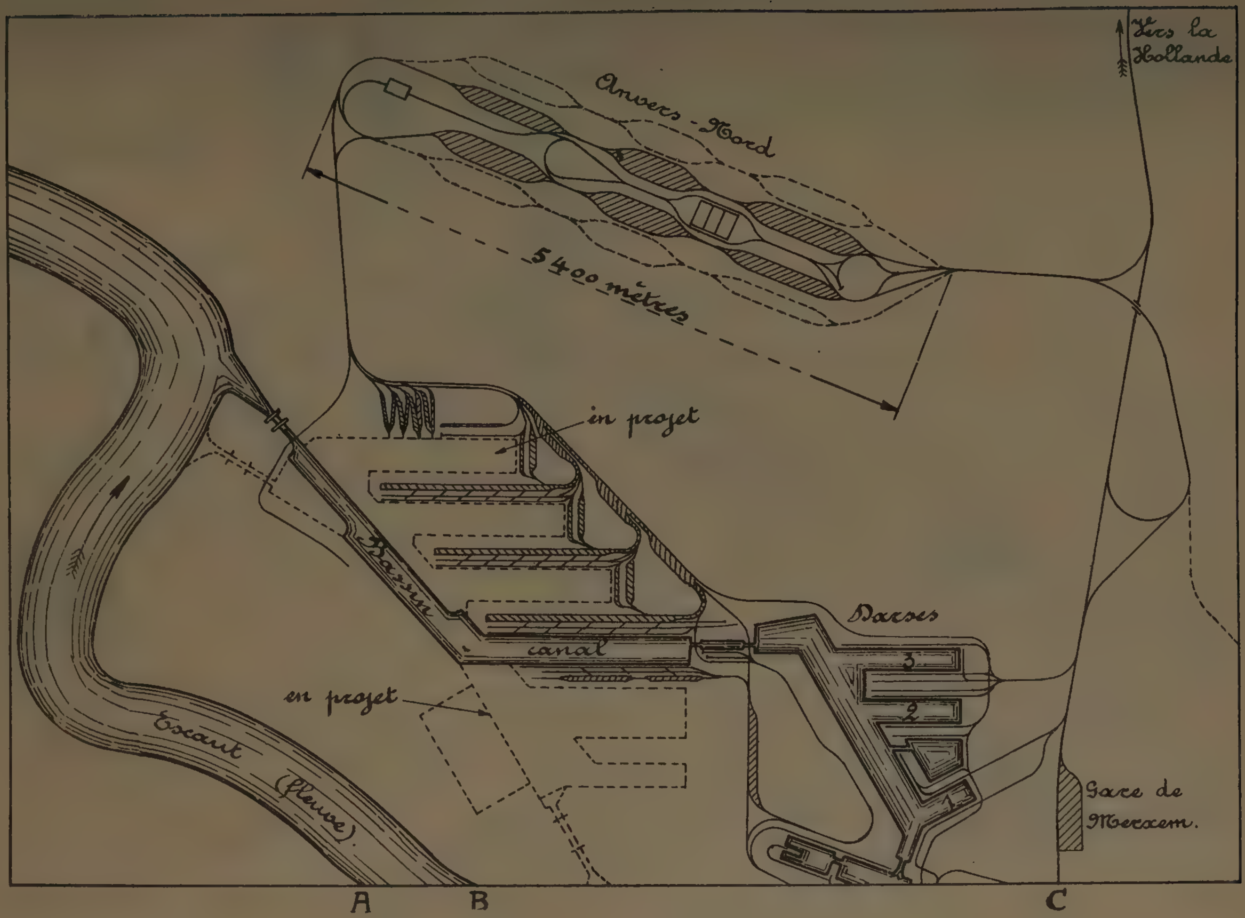


Fig. 4. — Port of Antwerp. — General view of Northern part.

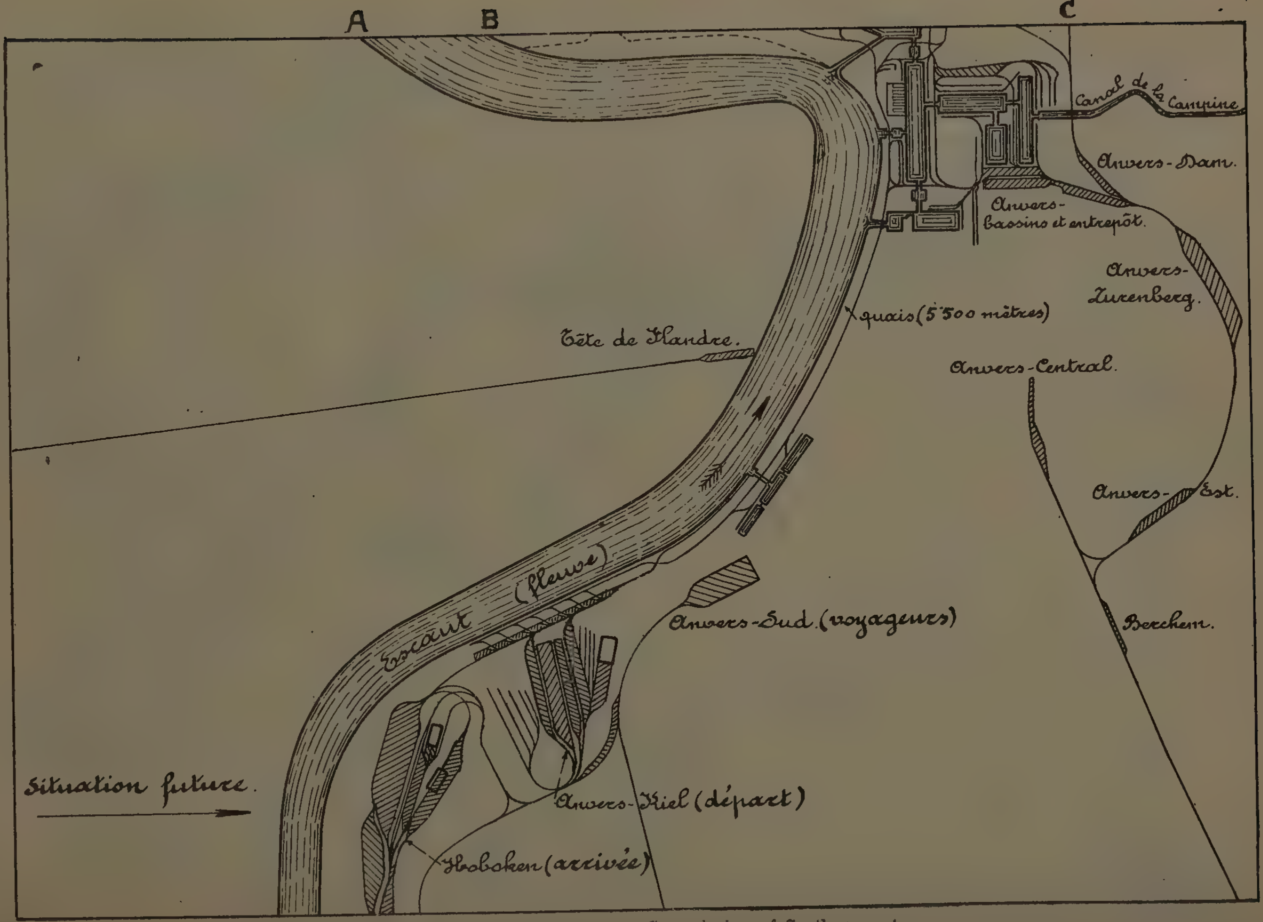


Fig. 5. — Port of Antwerp. — General view of Southern part.

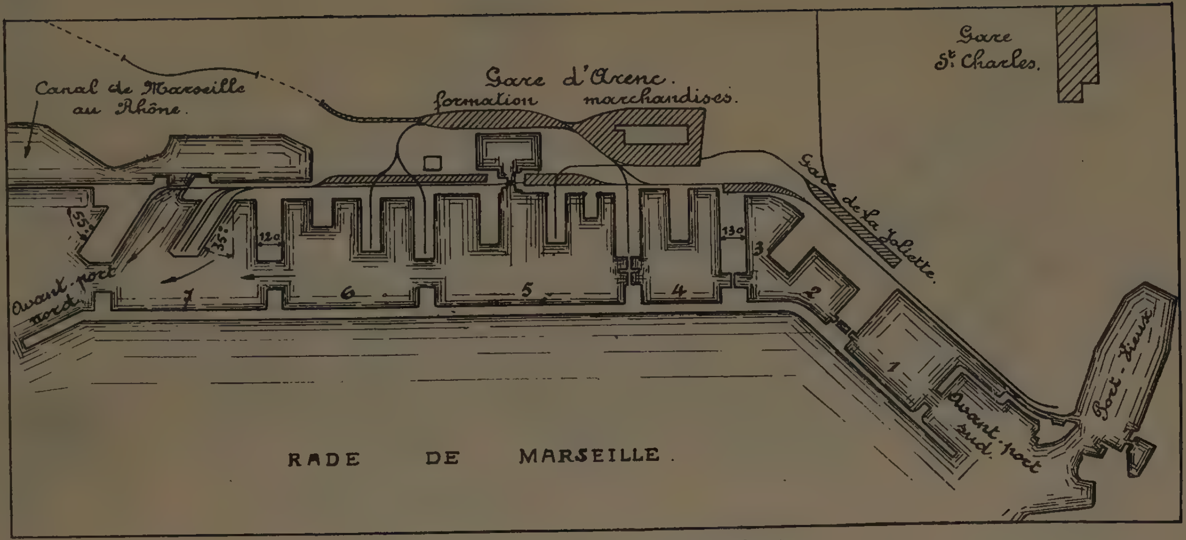


Fig. 6. — Port of Marseilles. — Present situation.

Explanation of French terms: Avant-port = Outer harbour. — Formation = Marshalling sidings. — Gare d'Arenc = Arenc station. — Marchandises = Goods yard. — Port-Vieux = Old harbour. — Rade de Marseille = Marseilles roadstead.

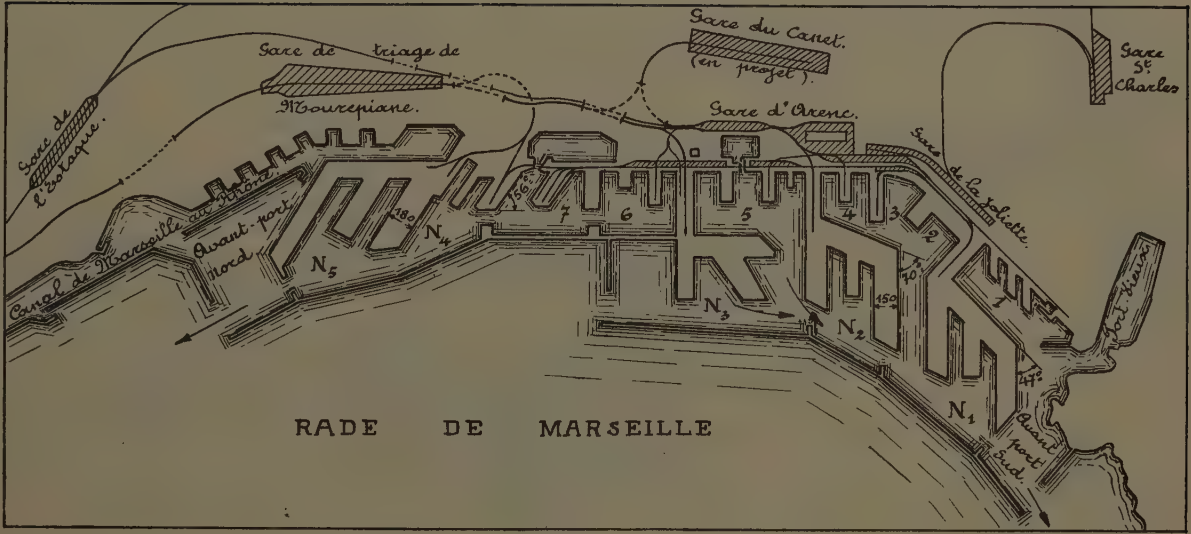


Fig. 7, — Port of Marseilles, — Proposed reconstruction.

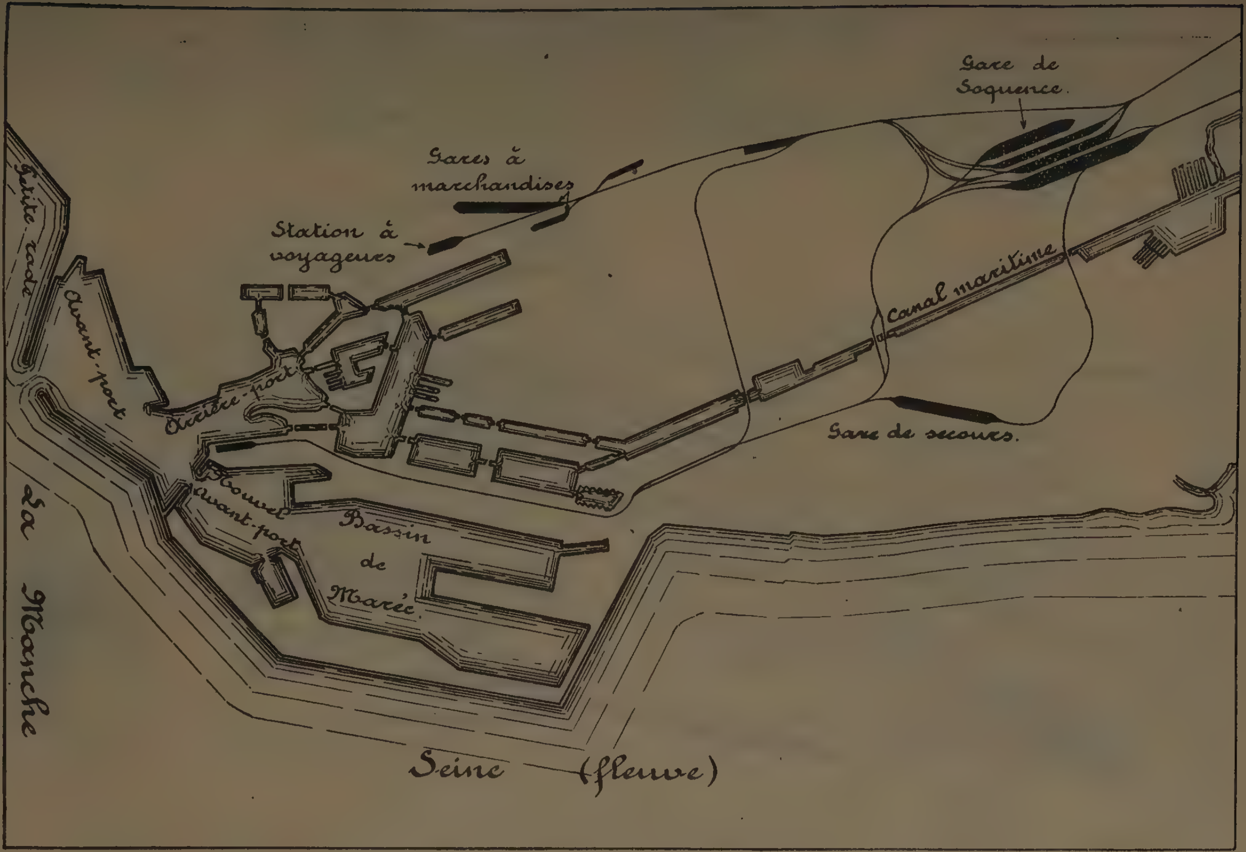


Fig. 8. — Port of Le Havre. — Present layout.

Explanation of French terms: Avant-port = Outer harbour. — Arriere-port = Back harbour. — Bassin de maree = Tidal basin. — Gare de secours = **Relief station.** — Gare maritime auxiliaire = Auxiliary harbour station. — Gares à marchandises = Goods stations. — Gare de Soquence = **Station at Soquence.** Nouvel avant-port = New outer harbour. — Petite rade = Little road. — Station à voyageurs = Passenger station.

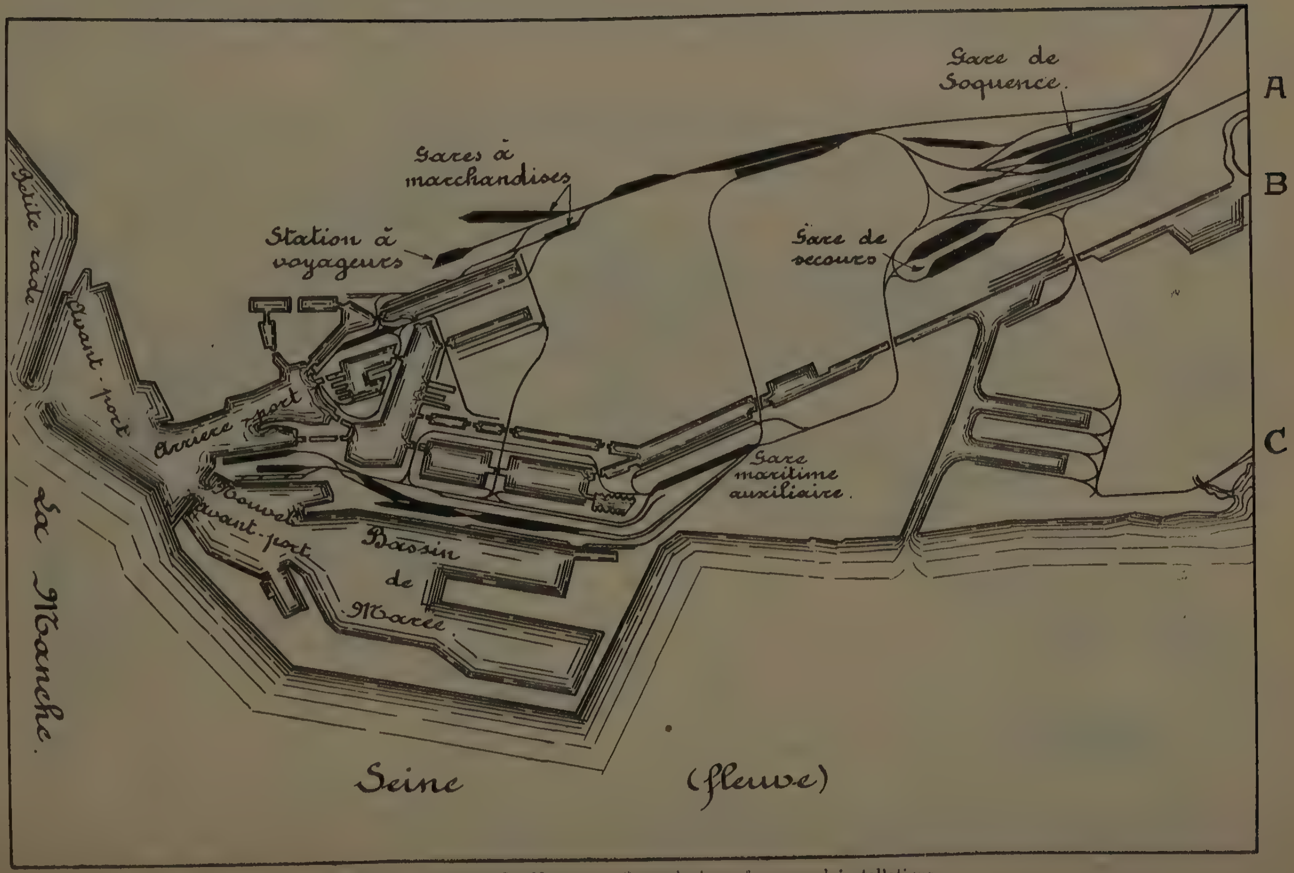


Fig. 9. — Port of Le Havre. · General view of proposed installations.

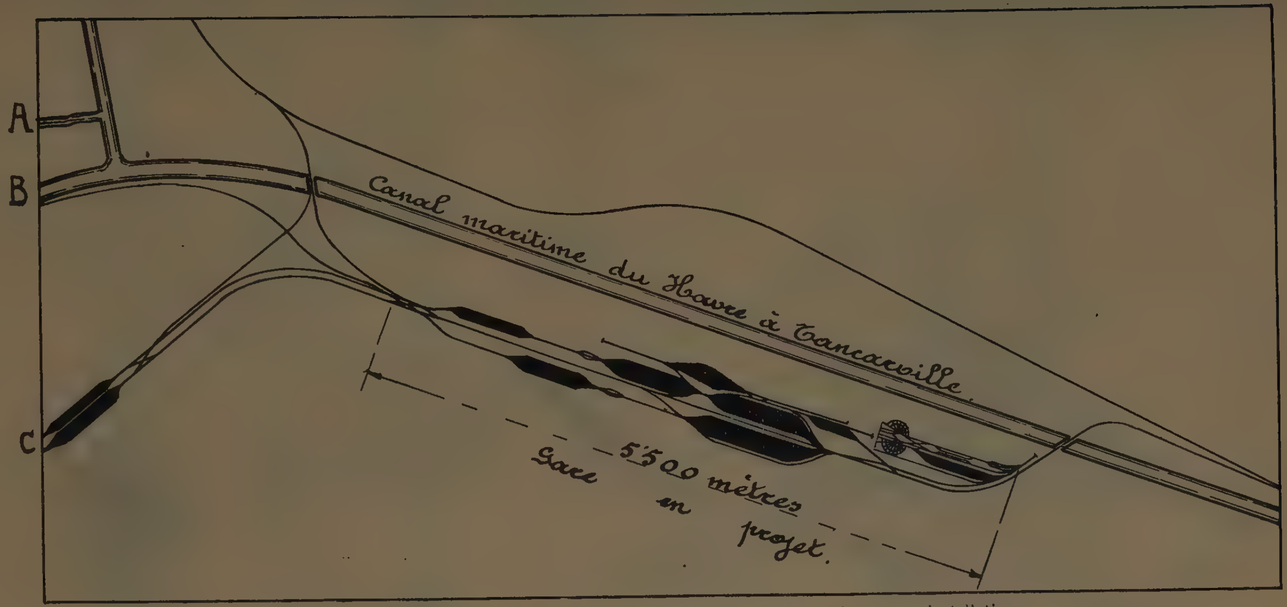


Fig. 10. — Port of Le Havre. — Proposed station for the service of the new installations.

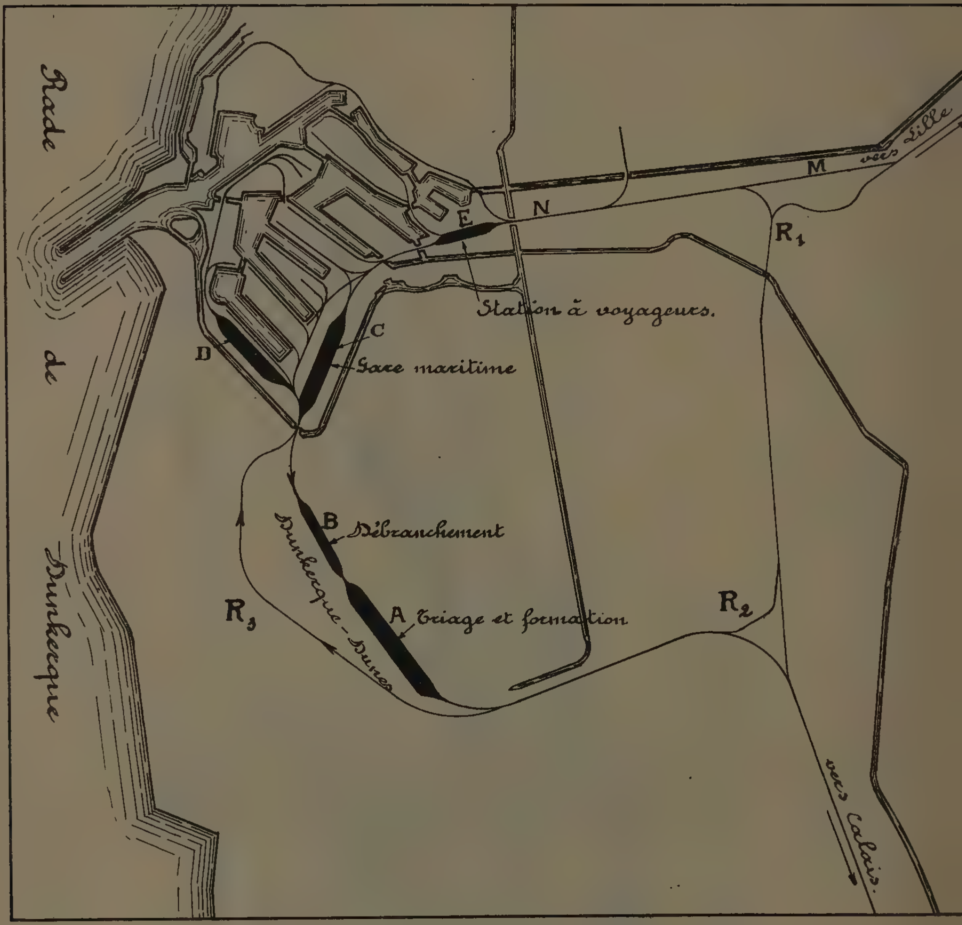


Fig. 11. — Harbour station at Dunkirk.

Explanation of French terms: Débranchement = Shunting sidings. — Triage et formation = Sorting and marshalling sidings.

3. That in the case of a river which has a double current, the basin is at an oblique angle or a right angle.

The perpendicular arrangement appears to have been general in the early days, but it is less favourable from the point of view of the installation of railway lines. In modern constructions the oblique angle preponderates, the basin being inclined towards the river mouth.

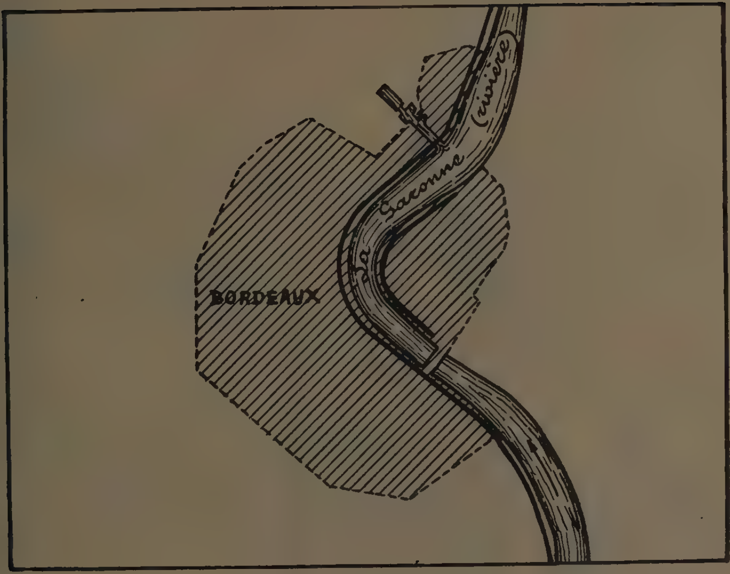


Fig. 12. — Port of Bordeaux.

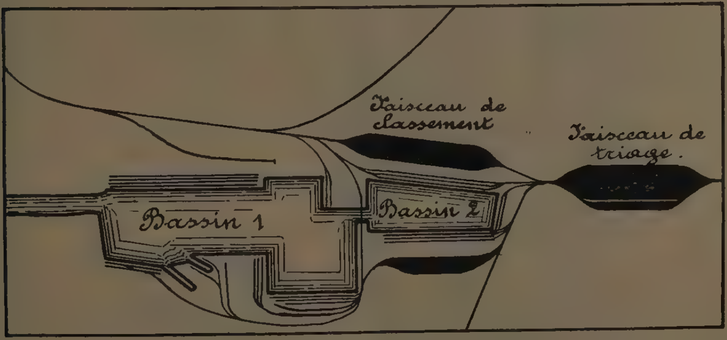


Fig. 13. — Harbour station at Bordeaux.

Explanation of French terms: Faisceau de classement = Marshalling sidings. — Faisceau de triage = Sorting sidings.

This arrangement is satisfactory from the point of view of silting up.

The question of angle becomes of less importance when the area of the basins is sufficiently large to render the movement of ships easier and safer.

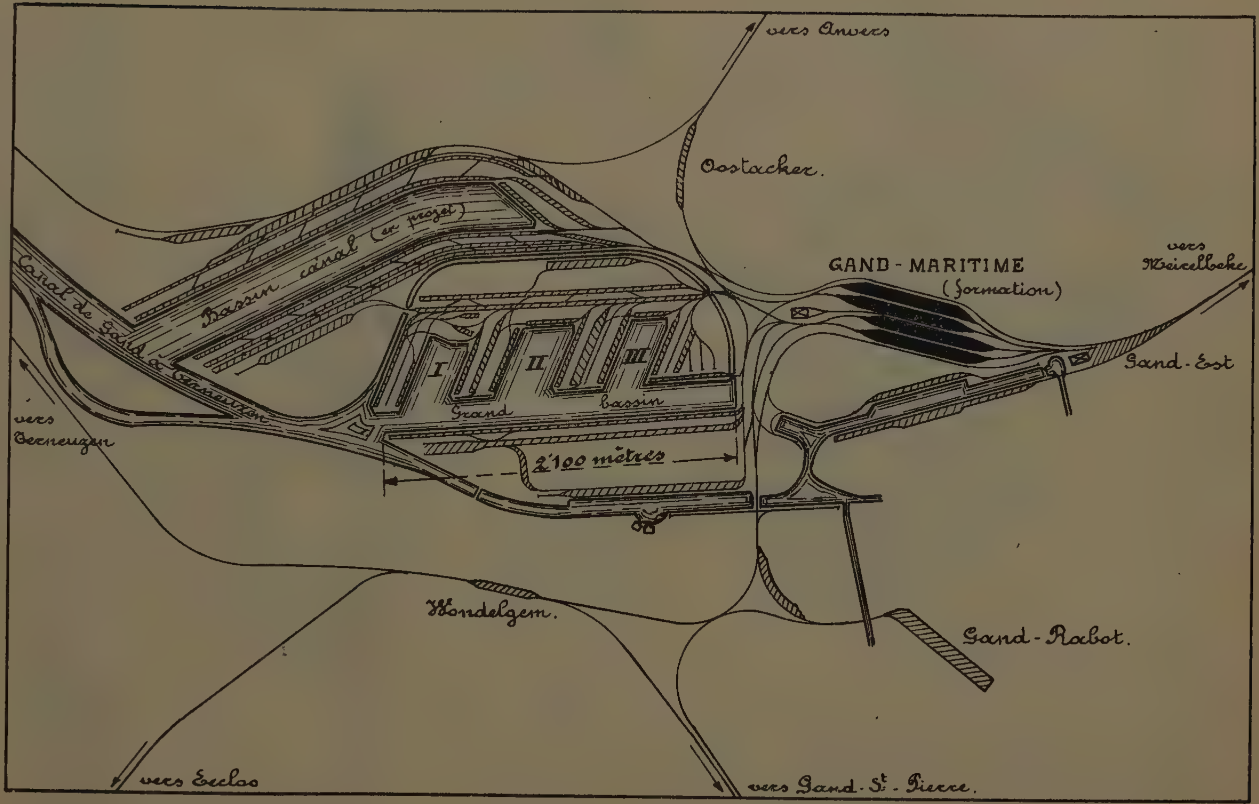


Fig. 14. — Port of Ghent.

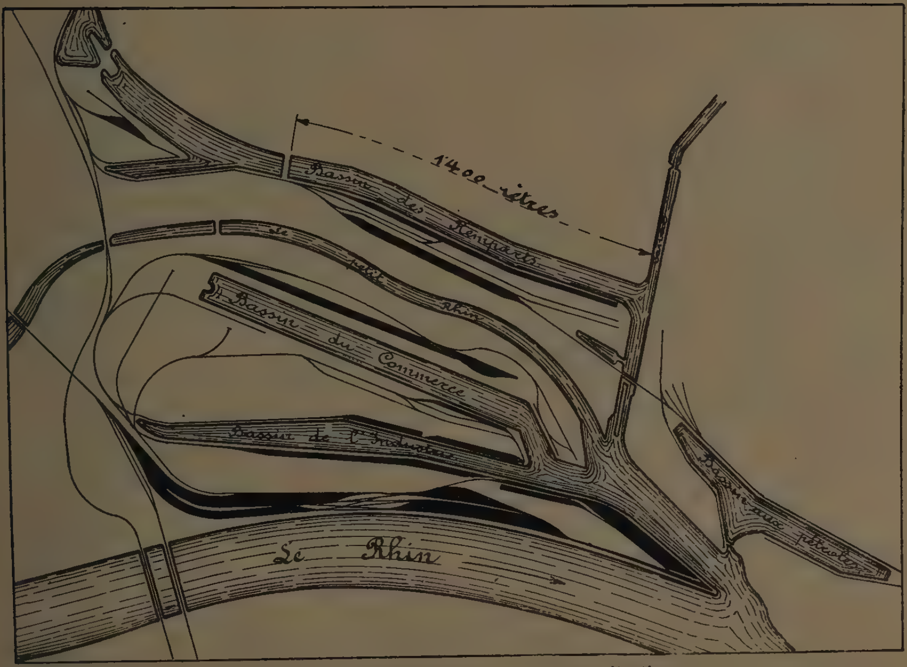
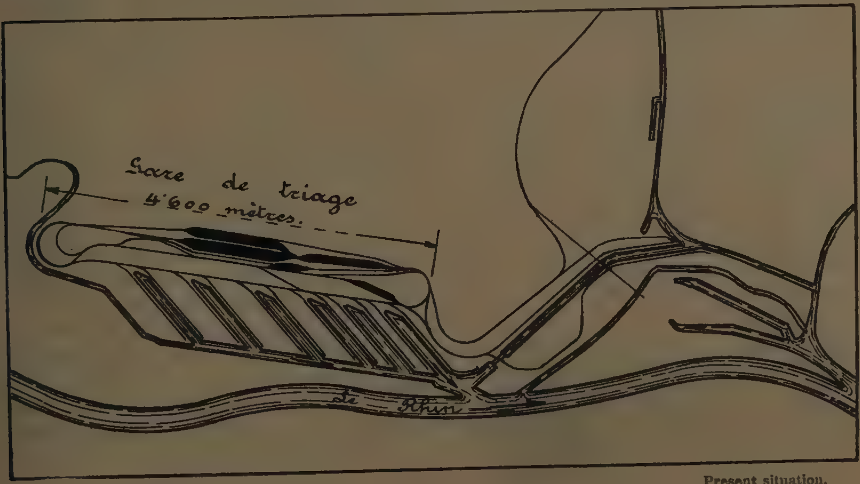


Fig. 15. -- Port of Strasburg. — Present situation.



Proposed additions.

Present situation.

Fig. 16. — Port of Strasburg. — Proposed reconstruction.

The railway must be able to construct:

1. Tracks serving the commercial installations;

2. Quay tracks for loading from wagon to ship or vice versa;

3. Accommodation tracks for loaded and empty wagons, to ensure a continuous movement of rolling stock to and from the quay sides.

From the point of view of the railway, if the harbour station is situated at A or at B (fig. 17), the laying of tracks for the service of the quays will be simple or complicated according to the angle at which the basins leave the canal.

In the case of site B, the oblique basins (D_2, D_3...) will entail unsuitable radii for curves, unless a very large amount of space is available. In this connection it is not desirable to have curves with a radius of less than 120 m. (6 chains).

Other things being equal, the more acute the angle, the less will be the width of the ground space (L), and, consequently, the more difficult will it be for the railway to instal the necessary tracks; less also will be the utilizability of the site within the acute angle C.

Theoretically speaking, and considering only the railway, one is led to favour an arrangement such as that shown in the lower part of figure 17. It permits also of having the station nearer to the harbour installations ($l < l'$).

As regards the length of basins, this, from the shipping point of view, is dependent upon their width, for a very long basin pre-supposes a large number of ships, both at the north and at the south (fig. 18), in which case it must be possible for ships to pass one another in either direction without fouling the ships lying at anchor. Each ship N lying at the quay-side can be served by lighters on the side opposite the quay, and ships moored in mid-stream B can be served by lighters *a* on either side.

From the railway point of view, the length of the basin must not exceed the total length of ship berths which correspond with the capacity of the tracks which can be laid on the quay wall or inner ground space.

In the case of very long basins, it may be desirable for the width to diminish gradually, the sides being in the form of a series of steps; this arrangement is also convenient from the point of view of railway working (fig. 19).

The *French Nord Railway* reports that the width of the dock walls at Dunkirk has been found somewhat insufficient. This width is, however, more than twice that of the basins. For the future, moles 200 m. (656 feet) in width are contemplated.

It may be remarked that, in view of the insufficient width of the quay spaces as compared with that of the basins, the apparently (though not really) paradoxical statement has been made that in certain ports there is too much water.

From the commercial point of view it must be possible to instal on the quay spaces such sheds, warehouses and free storage room as may be necessary. In general it may be taken that the commercial requirements will have been satisfied if the shipping and railway exigencies have been met, for in this case the maximum rapidity in ship arrivals and wagon movements will have been realised.

If the maximum working facilities are to be obtained, it would appear that, in the present condition of things, it is necessary to have quay spaces at least 300 m. (984 feet) in width between the basins. As regards the equipment of the quay

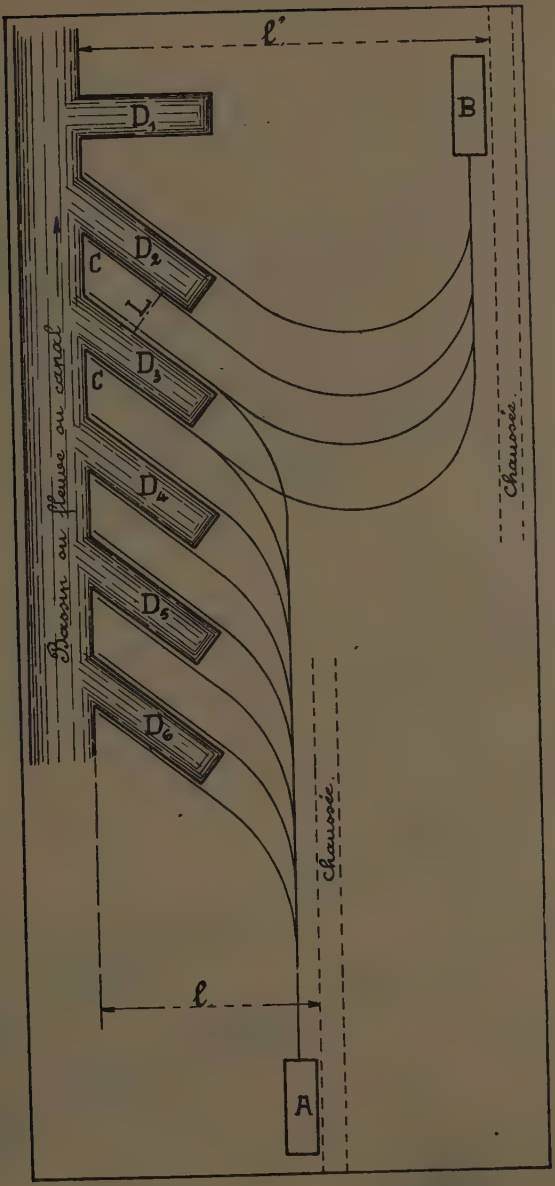
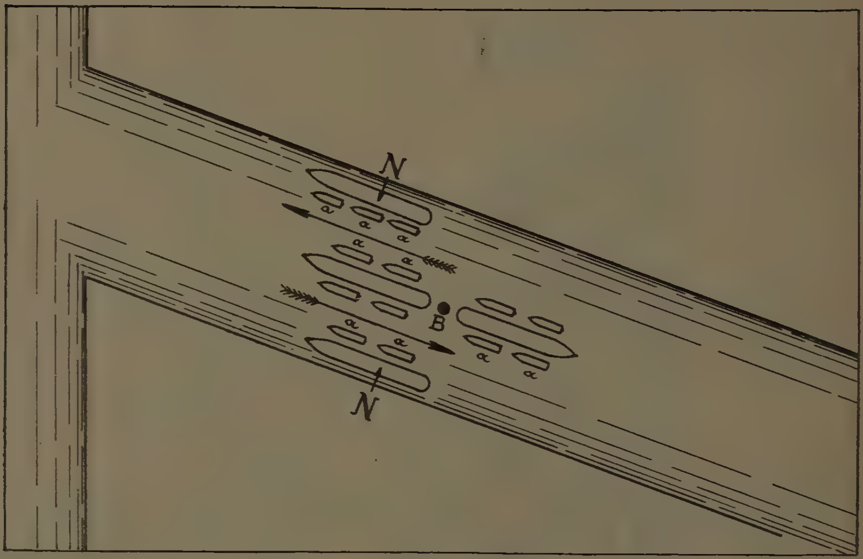


Fig. 17.

Explanation of French terms: Bassin ou fleuve ou canal = Basin, or river or canal. — Chaussée = Road



F'g. 18.

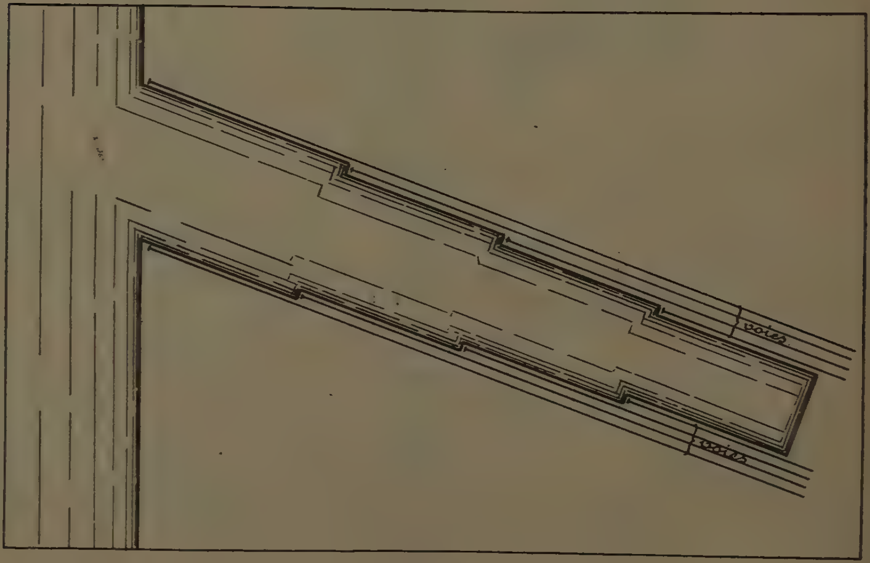


Fig. 19.

spaces, the arrangement shown in figure 29 appears to us to be among those most likely to ensure a maximum output.

There are not, in principle, any insurmountable difficulties in reconciling the shipping and railway points of view as regards working facilities. It is extremely desirable that the authority which is considering plans for a port should collaborate with the railway which will have to serve the port, and we cannot agree with the opinion expressed by one railway, which, in its reply to our questionnaire, declares philosophically that as harbour works are planned and constructed without the collaboration of the railway, the latter can only adapt itself to the exigencies created by the form of those works !

To sum up, what is necessary is to endeavour to adopt such arrangements as will, while satisfying the exigencies of both shipping and railway working, ensure the maximum facility and rapidity of the commercial operations.

The future installations of the port of Antwerp have been planned jointly by the port administration, the chamber of commerce and the railways, with a view to affording the best possible working conditions.

CHAPTER II.

General arrangements for service of quays.

The service of the quays in the various ports is performed by means of installations which resemble each other fairly closely when they date from the same epoch. By this remark we mean that with the process of time there has been a certain evolution from which each port has profited in its turn.

We believe, therefore, that it will be sufficient to describe the successive stages of a large port to enlighten the reader on this point.

In the port of Antwerp we find the three main types of quays, *viz.:*

a) Quays arranged *lengthwise* (free water quays, on the banks of the Scheldt, fig. 20); these quays are more than 5 km. (3.1 miles) in length;

b) Quays *surrounding tidal docks* (fig. 21), 12 km. (7.5 miles);

c) Quays *surrounding basins* communicating with a common canal (fig. 22 and fig. 4), 19 km. (11.8 miles) including the quays alongside the common canal).

The port of Antwerp thus comprises a total quayage of 37 km. (23 miles) and plans are under consideration for increasing this figure to 67 km.(41.6 miles). Obviously everything possible is being done to make this one of the most up-to-date ports.

All the quays are continuous, that is to say they are not constructed in echelon form.

The echelon form may be advantageous in certain cases, but the facilities it presents from the point of view of railway working can be equally well obtained, in the case of continuous quays, by means of double cross-overs or switches at suitable intervals.

Free water quays.

a) In the case of the *oldest quays* (South quays, down stream), two or three tracks, A, B, C, are laid along the quay wall (figs. 23 and 24).

Travelling gantry cranes run astride track A (which is by the edge of the river) on a track of 4-m. (13 ft. 1 in.) gauge, and these cranes also serve tracks B and C.

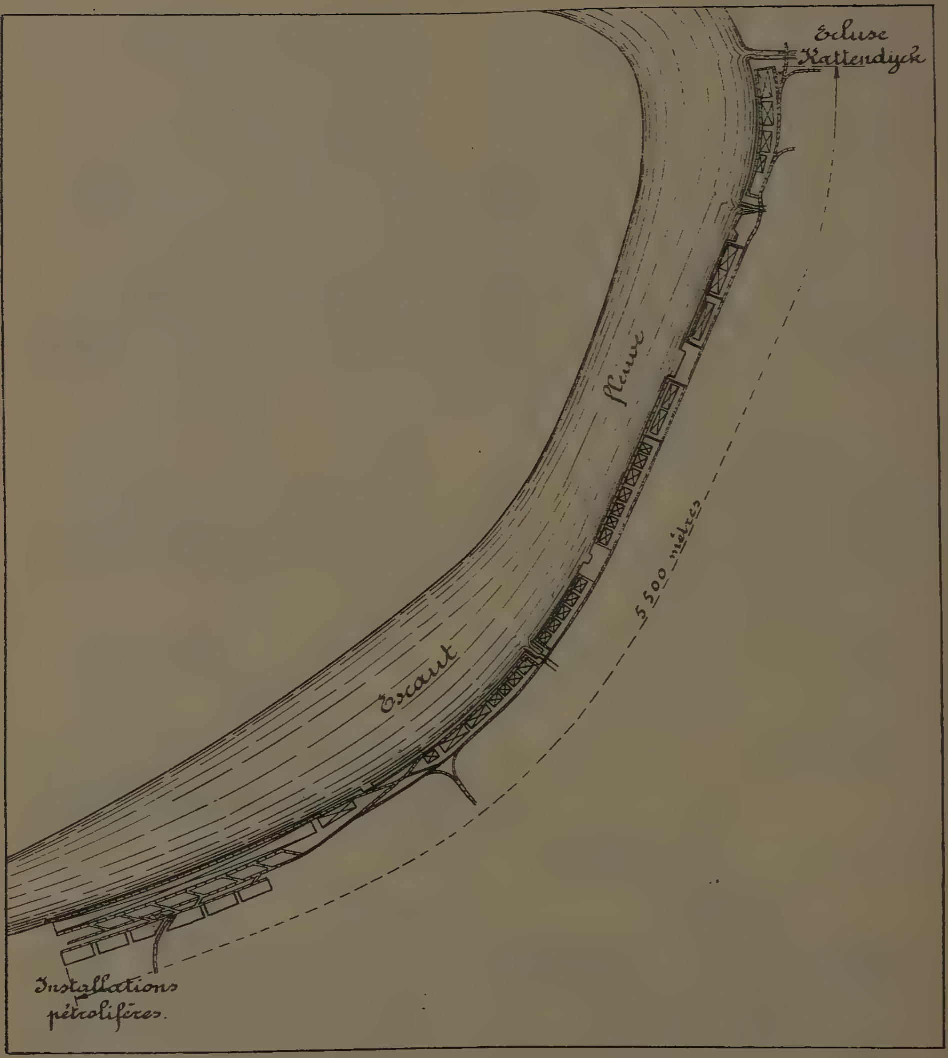


Fig. 20. — **Port of Antwerp. — Quays on bank of Scheldt.**

Explanation of French terms: Ecluse Kattendyck = Kattendyck lock. — Installations pétrolifères = Petrol tanks.

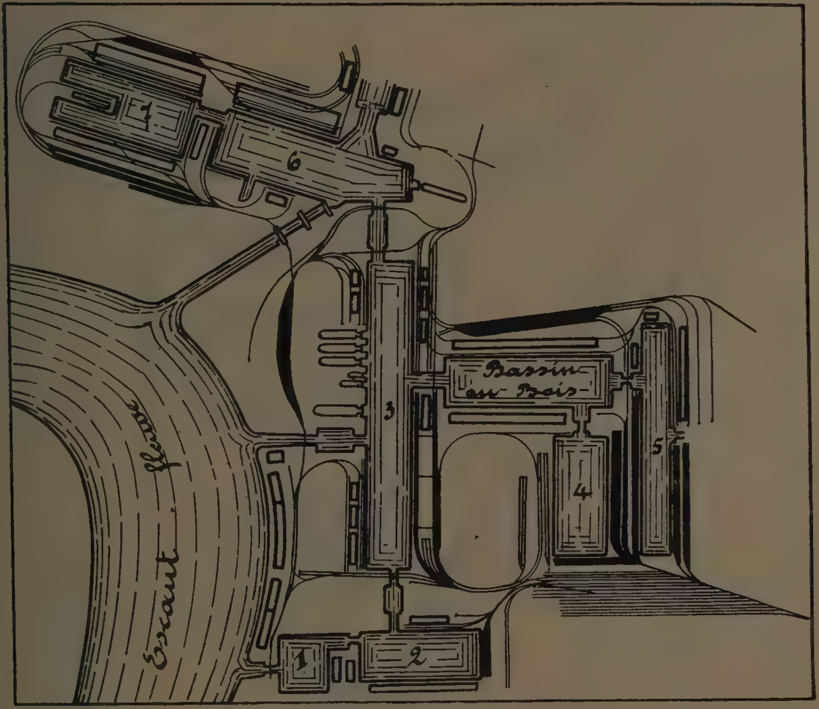


Fig. 21. — Port of Antwerp. — Central part.

Explanation. — Basins : 1. Bonaparte; 2. Guillaume; 3. Kattendijk; 4. Campine; 5. Asia; 6. Lefebvre; 7. America

Tracks A and B receive wagons containing goods for loading direct on to the ship, or empty wagons to be loaded directly from the ship. The third track, C, is used by wagons unloading directly on to the quays.

There is a fourth track, D, running through the sheds, and, finally, four or five tracks (1, 2, 3, 4) reserved for traffic, for shunting and for holding wagons awaiting despatch to the quays.

In some cases the installation is completed by open spaces situated between track C and the shed, and used for the temporary accommodation of goods which cannot be enshipped directly.

b) In the case of the *more recent quays* (South quays, up stream, figs. 25 and 26) we again find the tracks A, B and C, parallel to the river, but running under *semi-portal cranes* one side of which is supported by the sheds.

Under the sheds run two tracks, D and E, the one in the middle, the other on

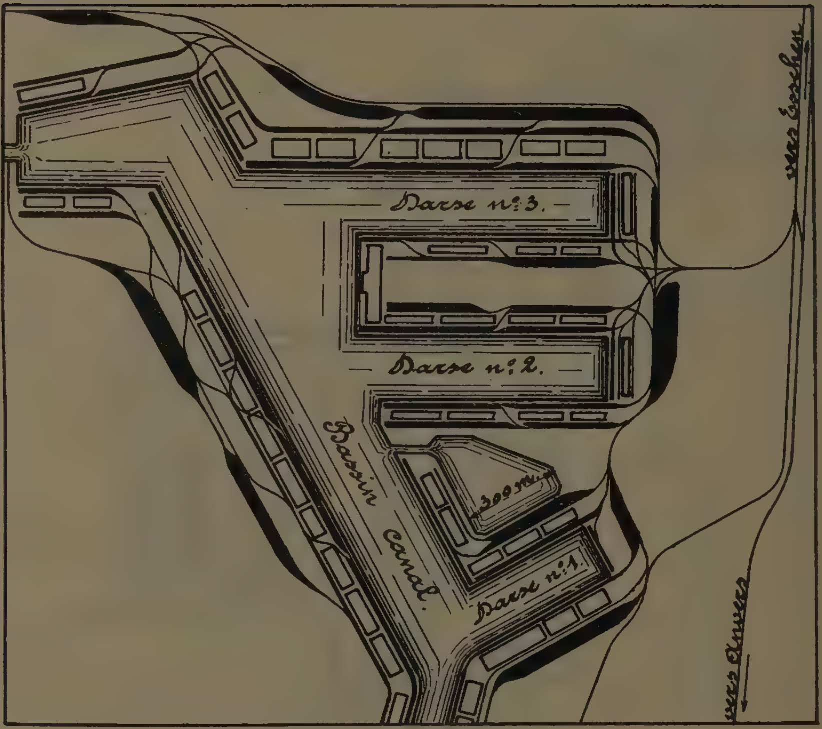


Fig. 22. — General view of basins Nos. 1 to 3, showing the connecting canal. (Bassin-Canal.)

the opposite side, for loading under cover from the ground, or unloading on to the ground.

There is then a group of about ten dead-end back-quay tracks (Nos. 1, 2...) of an average length of 60 m. (197 feet), used either for the sorting of wagons according to ship's hatches, or for their classification in the order in which they are to be unloaded, when their contents are to be loaded on to ships discharging at several ports of call.

Tidal docks.

The part of the port of Antwerp which one might call the inner port is formed of docks and basins (¹) with gates (figs. 21 and 22).

(¹) Old basins : Bonaparte, Guillaume, Kattendijck, Campine, Asia, Lefebvre, America.

New basins : basins 1, 2, 3, canal-basin and junction neck.

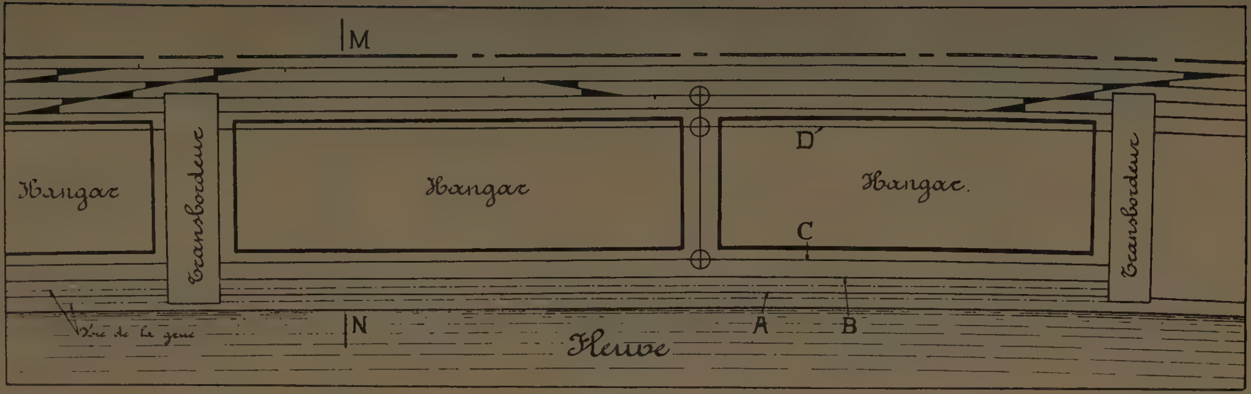


Fig. 23.

Explanation of French terms: Fleuve = River. — Hangar = Shed. — Transbordeur = Traverser. — Voie de la grue = Track for travelling crane.

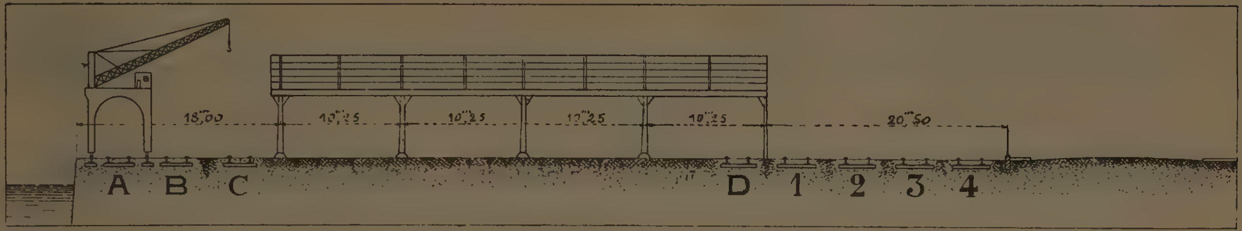


Fig. 24. — Cross-section at M. N. in figure 23.

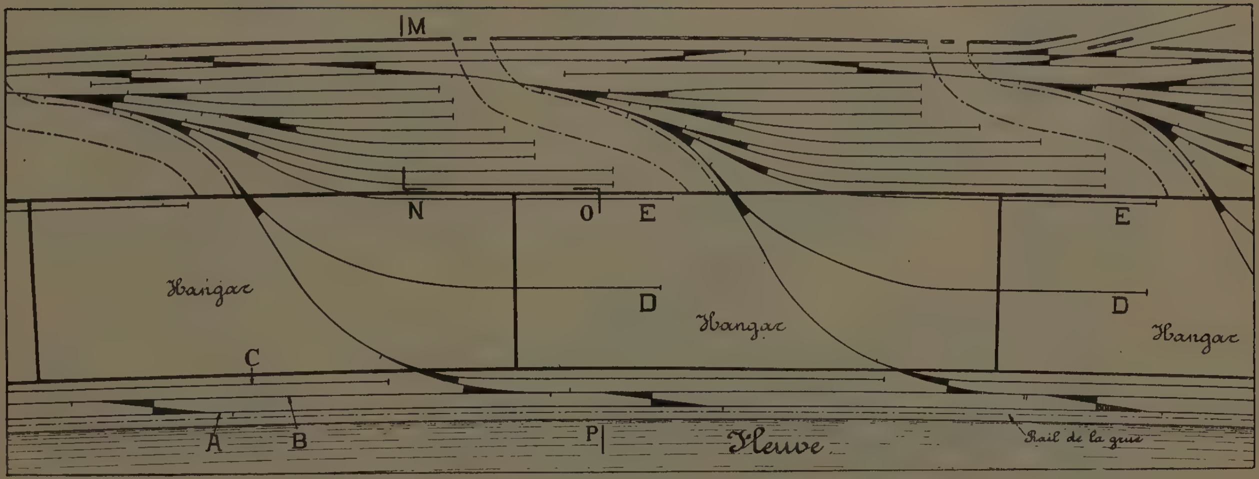


Fig. 25.

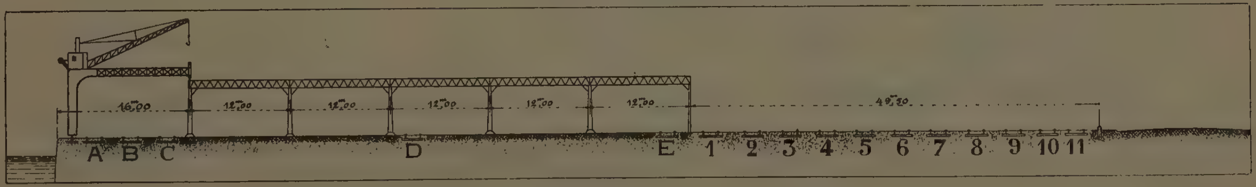


Fig. 26. — Cross-section at M. N. O. P. in figure 25.

A) The railway equipment of the *old inner basins* (figs. 21 and 27) differs very little from that of the old riverside quays, except that there are still some turntables but no traversers;

B) As regards the *new basins* (basins Nos. 1 to 3) (figs. 22 and 28), a characteristic feature is the existence of a group of back-quay lines for each « group of quays ».

These lines are laid near to the quays which they serve. They are in direct communication with the harbour station, and they receive wagons which are proceeding to the quays but which have still to undergo a final sorting (according to ship's hatches or ports of call). These groups of lines further perform a *regulating function*, retaining those wagons which the quays are temporarily unable to receive owing to delay in the unloading of wagons or because ships are overdue on account of fog or for other causes. Similarly, they hold empty wagons intended for the quays, when the latter could not receive them for the above-mentioned reasons;

C) Inner basins in course of construction and future inner basins (canal, entrance neck and projected basins):

a) In the part of the canal at present open or to be completed in the near future, the *northern quays* are being equipped as shewn in figure 29.

On a ground space 300 m. (984 feet) in total width there are, starting from the quay wall :

— Three tracks A, B, C, covered by travelling gantry cranes, the supports of which are 15 m. (49 feet) apart;

— A free space 17.75 m. (58 feet) wide between tracks, where goods can be deposited on the ground;

— A track D from which goods can be also deposited;

— Sheds 31.50 m. (103 feet) deep, served externally by three tracks F, the track nearest to the shed being, in principle, reserved for the loading of wagons with goods from the shed, the second track being free for through traffic, and the third, which is alongside the roadway, being used for transhipment between wagons and road vehicles;

— A roadway G, with a paved width of 12 m.;

— A space H, 11.75 m. (39 feet) wide, reserved for the construction of various buildings (offices and others);

— Groups of back-quay tracks M, on which are performed the final shunting operations, and where wagons returning from or proceeding to the quays may be accommodated temporarily.

These quays are reserved for ships taking goods for *export;*

b) The *southern quays* (fig. 29*bis*) are on the contrary reserved principally for ships bringing *imported* goods and taking away little or no goods for export or leaving in ballast.

On a ground space 350 m. (1 150 feet) wide there are, starting from the quay wall, four groups of two sheds each; the second and fourth groups comprise metal framed sheds H M of the latest type, 48 m. (157 1/2 feet) deep. The first and third groups comprise concrete sheds H B, also 48 m. (157 1/2 feet) deep; these latter sheds are two-storeyed and on the first floor level there is a platform projecting 4 m. (13 feet) within reach of the cranes. The latter run astride track A only.

The arrangement of the tracks for the metal framed sheds is the same as that on the northern quays, except that the free space between tracks C and D for the depositing of goods on the ground is only 9 m. (29 1/2 feet) wide.

The arrangement of the tracks for the concrete sheds is also the same, except that track D and the free space for the depositing of goods on the ground do not exist, and group F comprises 4 tracks instead of 3.

On the outside of the roadway G, space H extends for 17 m. (56 feet).

The three tracks A, B, C, at the quayside, and tracks D and F which serve the sheds, are connected with the backquay groups M by means of junction lines leading on to through lines with double slips within the groups M.

As will be seen from the diagram, instead of a succession of small groups of tracks, as in the case of the modern riverside quays (fig. 30), there are long groups of tracks parallel to the quays to be served. These groups are intersected by through lines in such a manner that the section comprised between two succeeding through lines corresponds to the length of two ship emplacements.

It would have been an advantage if it had been possible to lay a single group of tracks along the whole length of the basin, with intersecting through lines, but this idea had to be abandoned because it is not possible to cut all communication by cartage between the two sides of the quay; it was necessary, therefore, to narrow the group of tracks at intervals down to a single track, to permit of the laying of paved roads connecting roadway G with the similar roadway which is to be constructed parallel to it as soon as the basins projected at the north and south of the canal have been excavated.

As has been mentioned, the quays are subdivided into a certain number of sections P, each having a length of 300 m. (984 feet), which length corresponds approximately to that of two ships emplacements. Each of these sections has, therefore, its own separate railway tracks, so arranged as to afford independent shunting facilities for each section; in this way the bringing up and withdrawal of wagons can be effected with great freedom.

The advantages of this arrangement are the following :

a) The transhipment tracks are served without any light running of shunting engines;

b) The length of run of these engines is reduced to a minimum;

c) It is possible to accumulate groups of wagons carrying various classes of goods, so as to ensure the rapid loading of ships engaged in general transport;

d) Interruption in the handling of goods is reduced to a minimum;

e) It is possible to hold at any part of a group of tracks the reserve for any given quay, in view of the facility of communication between the different sections of the tracks.

It is this arrangement which will be adopted in future installations.

⁂

The chronological history of the development of the port of Antwerp (riverside quays or inner lock basins) enables us to follow the evolution of the railway service within the port. We find in the first place the system of the turntable road for the transfer of wagons from one track to another parallel track. Later, we find the same function being performed by traversers. Finally, we find adjacent lines linked up by means of points.

a) *Turntables.*

The Kattendijck basin, for example (fig. 27), constructed in 1860, was in the

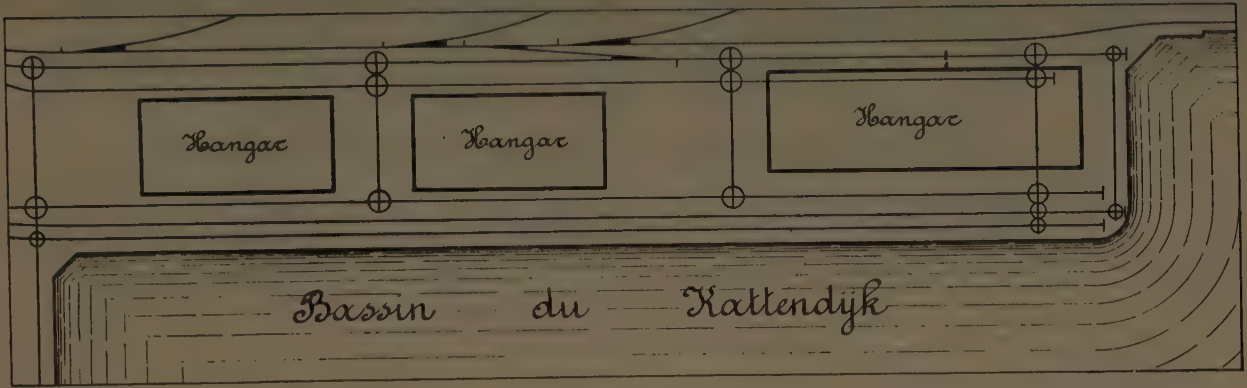

Hangar
Hangar
Hangar
Bassin du Kattendijk

Fig. 27.

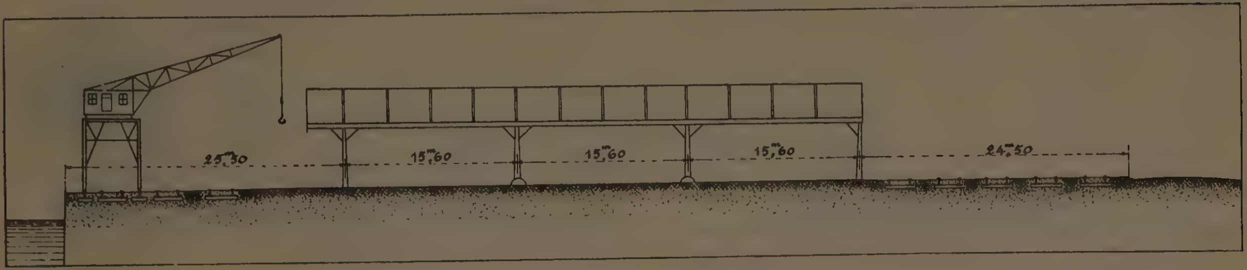

25m,30
15m,60
15m,60
15m,60
24m,50

Fig. 28.

first place bordered by tracks linked up by numerous turntables, a number of which have since been removed. The earliest turntables had a diameter of 4.20 m. (13 ft. 9 in.), and were later replaced, wherever possible, by turntables having a diameter of 6 m. (19 ft. 8 in.), in consequence of the increase in the length of vehicles.

It is unnecessary to add that this diameter cannot be increased beyond a certain limit, namely that imposed by the necessary restriction in the increase of the six-foot way.

Turntables are suitable where shunting is performed by hand, horse or capstan; but they cannot be used for wagons with a long wheel base, and they are not convenient for turning bogie wagons; they easily get out of order, they impede the passage of carts and lorries, and they are not conducive to rapidity of shunting.

b) *Traversers.*

The old South quays of the Scheldt, constructed downstream from 1874 to 1884, still have some turntables (fig. 23), but they rely principally on traversers.

In the early days these were not more than 10 m. (32 ft. 9 3/4 in.) long, but this length is no longer sufficient for the traversing of long bogie wagons, and consequently a large number of the old traversers have been replaced by traversers of 13 m. (42 ft. 8 in.) and 16.50 m. (54 feet) in length.

These traversers, which are operated by means of hydraulic and electric capstans, are of the type known as « sunk traversers ». In places where the laying of tracks linked up by points is not possible, the sunk traverser appears to be the best solution. Sunk traversers reduce the effective length of tracks and impede the running of engines. The increasing of their length reduces the space available for sheds and warehouses. Being controlled by capstans, their field of action is limited by the weight of the cable.

c) *Connections between tracks by means of points.*

The new upstream South quays of the Scheldt, begun in 1895 (fig. 30) no longer have either turntables or traversers, the wagons passing from one track to another by means of points.

This system gives a maximum shunting output, and allows of the handling of wagons of any length.

* * *

From the point of view of the sequence of movements during the operation of bringing up or withdrawing wagons, there are two distinct cases to be considered :

a) With the back-quay group of tracks situated upstream from the quay they serve : a single movement is necessary for each operation;

b) With the back-quay group of tracks situated to the right of the quay they serve : two movements are necessary for each operation, *i. e.* for bringing wagons to or withdrawing them from the quayside.

* * *

The maximum number of wagons which can be loaded or unloaded varies according to the circumstances :

A. — *Goods to be loaded on board ship.*

1. *The ship has not arrived when due.* — In this case the only « active » tracks are tracks C and D (fig. 29), from which goods can be unloaded *direct* on to the ground (*i. e.* the tracks situated on either side of the quay space in front of

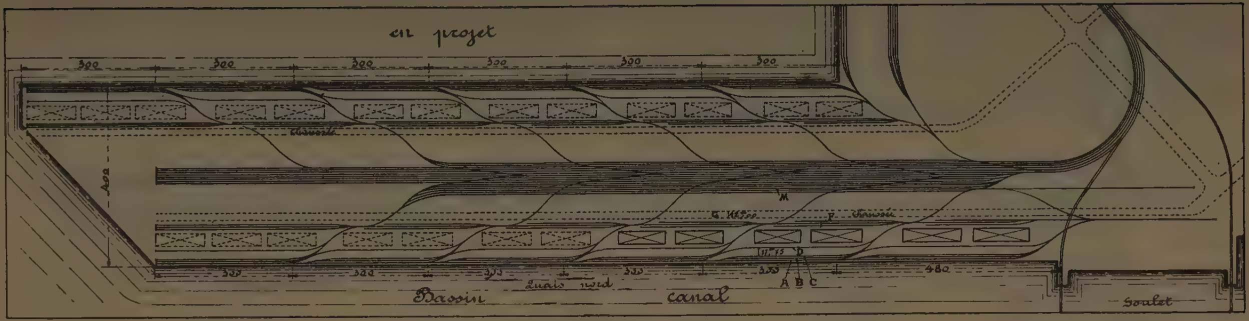


Fig. 29.

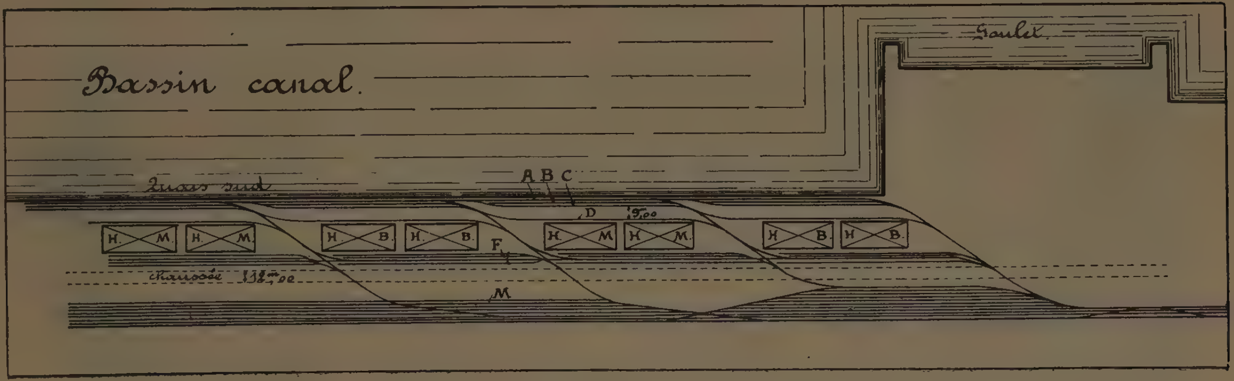


Fig. 29*bis*.

the shed) and the third track F on the far side of the shed. Tracks A and B along the waterside are « passive » and can only be used to hold wagons awaiting the ship or waiting to be placed on the tracks bordering the open quay space. The three tracks C, D and F can accommodate 39 wagons (13 wagons per track).

2. *The ship is at the quayside.* — In this case wagons can also be placed on the first two tracks A and B along the water edge. The number of wagons which can thus be brought up for unloading at one time is 65 per quay berthing space (5 tracks with 13 wagons each).

Tracks A and B receive wagons containing goods for direct transhipment; track C receives wagons containing either goods for direct transhipment or goods to be unloaded on to the quay. The same applies to track D on the north quays, tracks A, B and C being accessible to the cranes on these quays; this is not, however, the case with track D on the other quays.

B. — *Goods to be unloaded from ship.*

The bringing up of wagons is confined to the three tracks A, B and C, along the quayside, on which the wagons can be loaded direct. This means that only 39 wagons can be in position at a time at each quay berth.

At certain berths, track D is also accessible to the cranes, and in these cases that track is also used for the loading of wagons direct ex-ship, unless there are, at the berth in question, wagons containing goods for export which have to be unloaded on to the quay.

* * *

According to the French Nord Railway, the *maximum* number of wagons which can be held simultaneously at

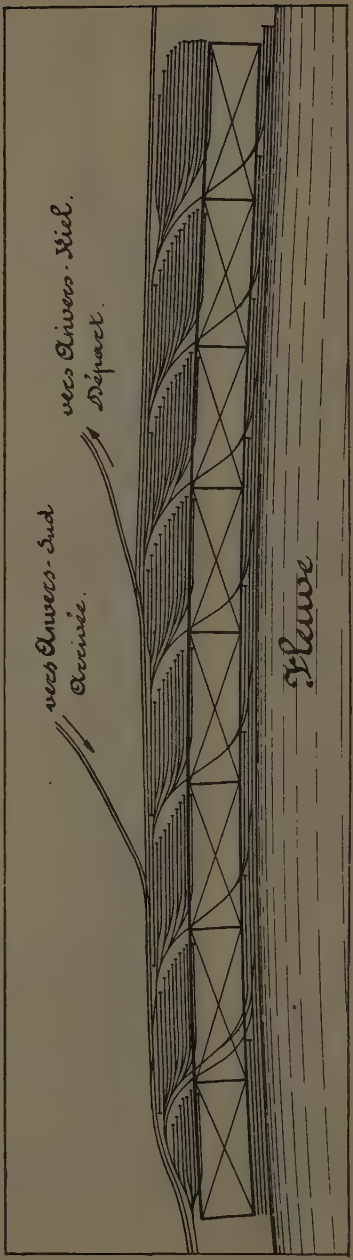


Fig. 30. — South quays.

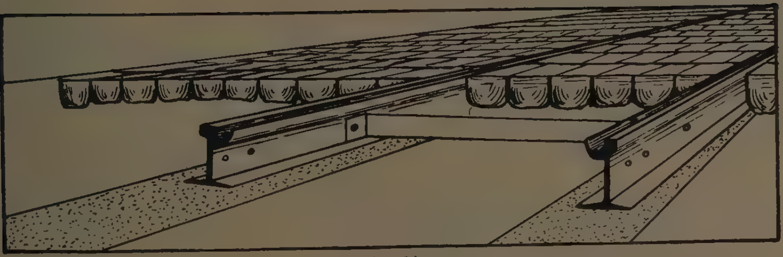


Fig. 31.

ship's side for loading or unloading is about forty, which is practically the same as the number indicated above in the case of the port of Antwerp.

In the ports served by the French Midi Railway the number of wagons which can be placed alongside a ship varies greatly, depending on the length of the quay section; it varies from 8 to 55, but is more often nearer 15.

* * *

If we examine the *French ports* we shall notice that, as in Belgium, the number of quay tracks depends on the traffic of the different sections of the quays.

At Dunkirk, for example, the number is, in general, three: the middle track, being connected with the two outside tracks, can thus serve as a feeder to those two tracks.

The sheds and warehouses are situated at the back of the quays and, in general, at a distance which allows of the unloading of goods on to the space between the quayside and the sheds. These sheds and warehouses are generally in a line parallel to the quayside, and are served by tracks parallel to the quay tracks on either side.

In sheds of very large dimensions, internal tracks are provided, as for example in the textile shed at Dunkirk.

Carts and lorries have generally access to every part of the quays, the surface of which is either paved or metalled.

Embedding the rails facilitates cartage. It may be interesting to note that at Dunkirk and Bordeaux in particular the rails are embedded in the paved roadway (fig. 31). In some harbours where the rails are also embedded, it proves difficult to maintain the flange groove if not protected by a guard rail or a filling piece playing the part thereof.

At Antwerp the question of extending the use of street switches of the tramway type is being investigated.

At Marseilles the distribution of rolling stock on the inner surface of the quays is effected by means of mechanical traction (motor tractors and Latil tractors). Shunting engines are used only for working complete trains.

* * *

In principle, wagons can only be withdrawn and replaced during intervals between working, that is to say during the night or, if in the daytime, during meal times or changes of shifts. In practice, however, the tracks are fed as and when wagons are unloaded, especially in the case of goods for direct transhipment.

The duration of interruptions in working varies, other things being equal, according to the existing arrangement of tracks; operations are more rapid when the tracks are connected by means of points than when they are served by traversers and, *a fortiori,* by turntables.

The situation of the back-quay tracks also affects the duration (as we have seen above).

In the new installations now in course of construction at the port of Antwerp, the arrangements mentioned above have been decided upon with a view to affording the best possible working conditions.

If the maximum working facilities are to be obtained it would seem that in the present state of things it is necessary to have quay surfaces of a width of at least 300 m. (984 feet) between adjoining basins. As regards the equipment of these surfaces, the arrangement just mentioned appears to us to be among those most capable of giving a maximum output.

CHAPTER III.

Equipment of quays for loading and unloading.

In the larger ports we find the greatest diversity in the equipment available for loading and unloading operations.

As a general rule, cranes are part of the port installations and do not belong to the railway.

Apart from quays reserved exclusively for certain goods, in which case the loading and unloading installations are of a special type and power, we believe it may be stated that what characterises a well equipped modern port is much more the number of cranes than their power. At the present day, however, the lifting power of cranes is scarcely over less than 3 tons, and the 5 ton-crane appears to be the most suitable.

This opinion is shared by the French Nord Railway Company, which considers that this lifting capacity is sufficient for all ordinary loading operations, and that its standardisation gives the best possible output. The Nord Railway of France, like ourselves, recommends the use of travelling gantry cranes, running astride the *whole group* of quayside tracks, thereby increasing their output without impeding the bringing up of wagons.

It must be noted, however, that an increase in the lifting capacity of cranes is accompanied by an increase in working expenses with a consequent increase in net costs. Lifting apparatus which is more powerful than absolutely necessary entails useless expense.

The type of travelling gantry crane in use at Antwerp, which is a crane astride 3 or 4 tracks, with a movable crane on the portal enabling the arm to cover 2 or 3 tracks beyond that, appears to us the type that has most to recommend it.

Example : the new cranes installed between the junction neck and basin No. 3 (fig. 33).

In determining the number of cranes to be installed, one should start from the principle that it is desirable to have one per ship's hatch; and as in general there are four hatches in ships of the usual type, this means that a quay section of the average length of 135 m. (440 feet) (the length of a large ship) must have 4 cranes, or one crane for approximately every 34 m. (111 feet).

* * *

At Antwerp, where there are some 700 cranes, we find :

1. In the oldest installations (old inner basins and old South quays), *movable hydraulic cranes of from 1 1/2 to 2 tons capacity*, of the gantry type, running on

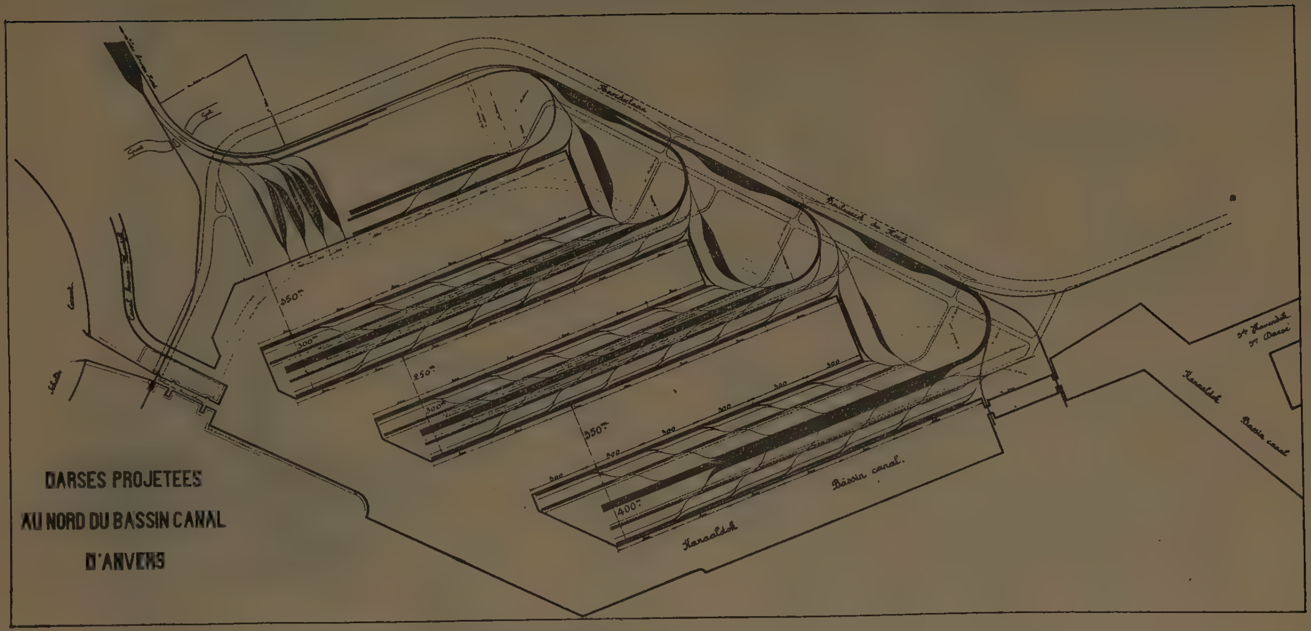


Fig. 32. — Projected basins north of the basin-canal in the port of Antwerp.

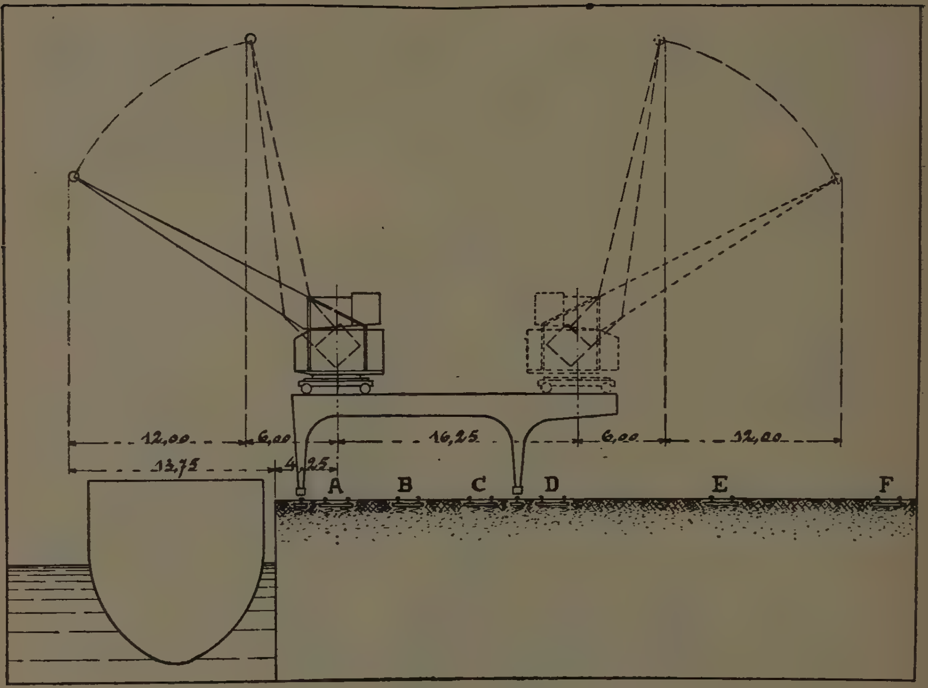


Fig. 33.

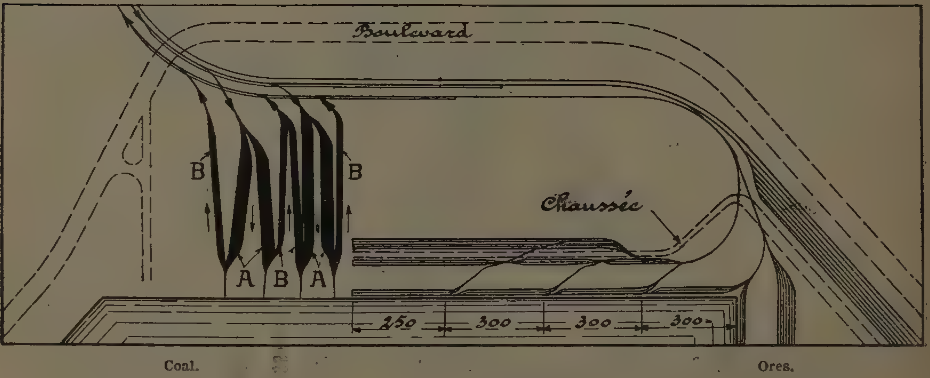


Fig. 34. — Port of Antwerp. — Proposed installation for the unloading of coal and ores.

a 4-m. (13 ft. 1 1/2 in.) gauge track, the travelling space of the portal being wide enough to take a railway track (¹); and other cranes with a travelling space of 9.10 m. (29 ft. 10 in.), affording room for two tracks under the portal (America basin).

2. *On the new South quays* the use of gantry cranes was no longer possible by reason of the presence of numerous points connecting the various railway tracks between the quayside and the sheds. Under these circumstances, 2-ton hydraulic *semi-portal* cranes have been installed, the inner side running on two rollers on the shed which is constructed parallel to the edge of the quay. In this manner the space between the quayside and the sheds is left entirely free for the movement of wagons.

In the most modern types of hydraulic semi-portal cranes, the driver's cabin, instead of being a fixture, is attached to the jib and, turning with it, gives the driver a better view of the load during the rotatory movement.

3. *At the new basins* (Nos. 1 to 3, and the canal-basin) where the most modern installations are concentrated, we find *movable electric gantry cranes*, with a capacity of 2, 3 and 5 tons, running on a 5-m. (16 ft. 5 in.) gauge track. The 2-ton and 2 1/2-ton cranes are jib cranes — with an adjustable jib — and their radius is 15 m. (49 ft. 2 1/2 in.).

The 3-ton cranes have a fixed jib and a radius of 16 m. (52 ft. 6 in.).

The 5-ton cranes have a radius of 18 m. (59 ft. 1 in.).

All these cranes run on rails. None of them can run at right-angles to the quayside.

The speed of the various crane movements is as follows :

1. *Lifting speed :*

For all cranes, 0.75 m. (2.46 feet) per second, with full load;

2. *Speed of slewing motion :*

For all cranes, 2.50 m. (8.20 feet) per second, measured at the hook. (The speed is 2.70 m. (8.85 feet) in the case of the 3-ton and 5-ton cranes.)

3. *The horizontal travelling speed* varies, but must not, under the regulations, exceed a man's walking pace.

In the three preceding paragraphs we have referred only to cranes in current use, but there are in addition;

4. *High power cranes :*

particularly :

A 50-ton fixed electric crane, with a 15 m. (49 ft. 2 1/2 in.) radius, the top of the jib reaching 35 m. (114 ft. 10 in.) above the ground;

Two 30-ton movable electric cranes;

A 120-ton fixed electric winch;

5. *Floating cranes :*

Apart from floating cranes of low capacity, there is a 150-ton electric crane, with a rotating jib. The top of the jib reaches 55.20 m. (181 feet) above water-level.

* * *

The quay output varies according to the capacity of the cranes in use and the nature of the goods handled. This is equivalent to saying that the phrase « average tonnage of goods handled per metre of quay » has scarcely any meaning if the average is that of *all* the quays in a port. Cranes of even low capacity could, if there were four to a ship

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(¹) Radius 11.5 m. (37 ft. 9 in.), maximum height of jib, 14 m. (45 ft. 11 in.). The jib can be lowered.

(135 m. [440 feet]), and if they worked continuously, deal with from 2 000 to 3 000 tons per annum per metre of quay, and even more.

The phrase just quoted only has a meaning when it is a question of a given class of goods, and even then it must be specified whether these goods are handled at an ordinary quay or at a quay specially used for those goods.

Having made this reservation, we may add that the French Nord Railway Company reports that at Dunkirk the average tonnage of goods handled per metre of quay per annum is a little more than 500 tons.

The French Midi Railway Company reports that at Bordeaux and Bayonne the average output amounts to as much as 800 tons.

Special sites for given classes of goods.

It may be desirable to reserve special sites in ports for certain goods, for the following reasons :

1. Danger resulting from the presence of the goods within the harbour installations (for example, in the case of mineral oils, the danger of fire).

Thus, at Antwerp the « oil installations » have been concentrated at the extreme upstream end of the new quays on the Scheldt, thereby protecting the harbour installations from the danger of fire. In order to limit the damage in case of fire, trenches have been dug around the oil tanks to retain the oil in case it escapes from the tanks;

2. When the goods in question give rise to a large amount of traffic of a permanent nature (ores, coal, artificial manures, cereals, timber, etc.), it is possible to convey them in complete trains direct from the interior to the quays or similarly to despatch them from the quays inland, so that there is no shunting in the harbour stations, which are then no more than transit stations;

3. Given the same conditions of size and permanence of traffic, these special sites can be equipped with appliances appropriate to the nature of the goods, thereby obtaining a much greater output (grab cranes, high capacity cranes, wagon tipping devices, belt conveyors, grain elevators, etc.);

4. Goods which have to be deposited in store before they can be re-despatched (potash warehouses at Antwerp).

At Antwerp, in the vicinity of the America basin, there are vast silos for the storage and *mechanical handling of grain*, with a capacity of 250 000 hectolitres (687 500 bushels).

The very modern *potash warehouses* have a capacity of 140 000 tons, and 6 000 tons of potassium salts can be handled per day, while 1 000 sacks can be filled per hour.

The belt conveyors for sacks can take 750 sacks of 100 kgr. (220 lb.) each per hour, at a speed of 80 m. (262 1/2 feet) per minute; the belt conveyors for loose goods can carry 200 tons of salts per hour.

These installations serve quays Nos. 152 to 158, and, with an equipment of four 5-ton cranes and three 2 1/2-ton cranes, ships can be *unloaded* at the rate of 2 000 tons of loose goods and 750 tons in sacks per shift of 8 hours.

For goods for *export*, the three gantry cranes on quays 154 and 156 can each load 1 200 tons of loose goods, or a total of 3 600 tons, per shift of 8 hours.

The loading of sacks is effected by means of three 2 1/2-ton cranes, and an average rate of 250 tons per crane, or

750 tons per shift of 8 hours, can be attained.

Loading into wagons for re-despatch to the interior is effected with the help of a special appliance comprising a conveyor worm. This appliance can deal with 300 tons, or the equivalent of about 20 wagons for one shift of 8 hours.

The *nitrate sheds* are situated along quays 178 to 182. They can hold 72 000 tons. They are served by five quay tracks and by a sixth loading track which runs along the rear side of the sheds.

The loading capacity on the fifth and sixth tracks may reach as much as 180 wagons per day of 8 hours. The loading is done by hand.

The sacks extracted from the holds and deposited on deck by the ship's own tackle are picked up from there by a crane and deposited on the quay for loading on to wagons or to be placed in the sheds.

One ship can in this manner load *an average of 140* wagons per day.

Special installations are also to be provided for the loading of *coal* and *ores* in the port extensions at present under construction.

The northern part of the basin nearest to the harbour station at Antwerp-North, the digging of which is projected, will be reserved for coal transport. There will be an installation of high capacity for transhipment from wagon to ship (fig. 34).

One of the plans under consideration would comprise four unloading posts at intervals of 100 m. (328 feet). Each post would have two groups of tracks, A and B, the tracks having an average length of 300 m. (984 feet): group A would be for the reception of loaded wagons, and group B for wagons which had been unloaded. The capacity of group A would be double that of group B.

The wagons would first of all be brought from the arrival yard on to the waiting sidings, comprising tracks 600 m. (1 968 feet) in length, and thence run in groups on to siding A. The tracks in siding A would have a gradient of 10 mm. per metre (1 in 100) down to the tipping platform, towards which the wagons would run by gravity alone.

The group of tracks B would have a gradient in the opposite direction of 14 mm. per metre (1 in 71), rolling resistance being greater in the case of empty than of loaded wagons. The empty wagons on leaving the raising platforms would thus also run by gravity.

Shunting engines would remove empty wagons from siding B and take them on to waiting sidings situated on the side of the main lines opposite to the waiting sidings used for loaded wagons. Further, the entrance tracks to sidings A would cross above those connecting the extremities of sidings B. This arrangement would completely separate the routes of empty and loaded wagons.

A system which also merits attention is that adopted at Liverpool, in which the wagons are tipped into a hopper whence the coal falls on to belt conveyors, which carry it to the desired part of the ship.

This system may, moreover, be supplemented by the « coal antibreaker » in use at the Blythe Dock in the port of Newcastle.

The eastern part of this dock is, we understand, reserved for the handling of ores.

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At *Dunkirk* also certain quays are specialised :

Examples :

The « Freycinet XI » for *coal*. This post is equipped with four traversers, with buckets having a capacity of 5 tons, each capable of an output of from 80 to 100 tons per hour, whether for unloading into barges or into wagons; this post is served by 3 quay tracks, all of which can be used for loading, and which can be supplied with rolling stock as quickly as it can be dealt with by the traversers.

The « Freycinet X » comprises a post specialising in the handling of *ores*. Grabs are used, and there are also 4 cranes, the whole installation having an output of from 180 to 200 tons per hour. It is served by 3 quay tracks.

At the end of dock V there is a *granary* which is in communication with the two unloading posts installed on « Freycinet X ».

The posts on « Freycinet X » are connected with the granary by means of four conveyor belts on to which the grain is discharged from suction elevators on lighters standing between the quay and the ship. The output of each conveyor is from 80 to 100 tons per hour.

At *Marseilles* the Chamber of Commerce is principally responsible for the quay equipment, which comprises :

— Hydraulic tower cranes of from 1.25 to 3 tons capacity, with a radius of from 8.30 to 10.50 m. (27 ft. 3 in. to 34 ft. 5 in.) beyond the quay edge;

— Electric tower or semi-portal cranes of from 1.5 to 4 tons capacity, with a radius of 10 m. (32 ft. 9 3/4 in.);

— American portal cranes with a capacity of from 5 to 10 tons and a radius of from 11 to 13 m. (36 ft. 1 in. to 42 ft. 8 in.).

The lifting speed varies between 1 minute 30 seconds and 1 minute 50 seconds according to the type of crane.

PART III.

CHAPTER I.

Methods of port operation.

In *Belgium* the railway bears the initial cost of the railway installations of a port when they are for general use, it being understood, of course, that the necessary ground space is placed at its disposal. The railway does not reimburse itself for this expense by a special charge on goods proceeding to or from the port; it is treated as part of the railway's general financial charges.

Subsequent work in connection with the railway installations is dealt with in the same way.

The cost of the harbour station, including the cost of the ground, is borne entirely by the railway.

The port of Antwerp being served by two stations : Antwerp-North and Antwerp-South, the railway administration, wishing to leave the trader free to send his goods to any quay within the port, fixes its charges for a single distance, which is the average of the distances from the departure station to the two stations at Antwerp.

Apart from this peculiarity, the Belgian tariffs do not pretend to « correct geography », that is to say, consignments to the various ports of the country are charged according to the distance between the departure station and the port of destination. Each port thus maintains the advantage of its geographical position.

At Antwerp and at Ghent the port is controlled and operated by the municipal authorities of those towns, but the railway installations are operated by the railway administration.

There is no official liaison organisation between the two controlling bodies, but there is collaboration whenever circumstances require it. Further, the municipal authorities and the railway administration are always ready to be guided by the views expressed by the chambers of commerce or by industrialists.

Tracks serving non-specialised quays are regarded as a prolongation of the goods sidings of the station concerned. The service of these quays is free, but when the tracks serve workshops, warehouses or private establishments they are regarded as private sidings.

* * *

In France the law of 12th June 1920, with a view to coordination of working, created the system of « autonomous ports ».

The object is to constitute a local authority capable of exercising general control : 1. over the port itself; 2. over all the organisations which participate in its activities (Bridges and Highways, Railway, Customs, Public Bodies).

The « autonomous port », while remaining a State port, is a public establishment subject to civil law. It is administered by a board which decides all questions connected with construction, equipment and working. The port controller in an executive agent of the board of management, but he also represents the Government on the board.

The board is composed of 15 members, 6 of whom are elected by the chamber of commerce, the others being chosen from among the principal professional organisations concerned. It also comprises delegates of the railways and of the relevant ministerial departments.

The Minister of Public Works retains a right of veto.

The only « autonomous ports » are those of Le Havre, Bordeaux and Strasburg.

At the head of the *non*-autonomous ports there is a controller, who is the chief engineer in the service of the Ministry for Bridges and Highways. He is assisted by a consultative committee consisting of 15 members chosen from among the members of the chamber of commerce, the municipal council, the general council and the principal users of the port.

In general the French railways which hold concessions in respect of port railways themselves bear the cost of construction of the superstructure and of providing the necessary installations.

They are authorised to reimburse themselves for this cost and for working expenses by charging a special tariff on goods proceeding to or from the ports.

The harbour stations are included in the railway installations.

On the Paris - Lyons - Mediterranean Railway (port of Marseilles), the lines serving the quays are considered as private lines and not as a continuation of the goods yard; the service of these lines is not free. On the French Midi Railway, on the contrary, the quay lines are regarded as a continuation of the goods yard, though tariffs are imposed on certain sections.

In the case of the Nord Railway, quay lines are not assimilated to private sidings; nor are they regarded as a continuation of the goods yards, the time taken in handling operations not being the same as in the case of goods yards. Service on these lines is in general free of charge.

The Paris-Lyons-Mediterranean Railway does not bear the initial cost of railway installations in the port of Marseilles. These belong to the State, but are operated and maintained by the Paris-Lyons-Mediterranean. For the working concession granted to it, the Paris-Lyons-Mediterranean Company pays the Chamber of Commerce, in respect of all goods transported in either direction, a royalty of 1.10 or 1.175 fr. per ton, according to the nature of the goods. This royalty is added to the charge for transport over the quay lines.

It may be noted that the railway lines comprised within the concession held by the Docks and Warehouses Company (« Compagnie des Docks et Entrepôts ») belong to that company and are operated by it on tariffs fixed by the company.

The cost of equipping the lines is borne by the Chamber of Commerce.

The Chamber of Commerce owns and administers the open sheds and public appliances which it has provided on ground belonging to the State.

⁂

The French State Railways report that, when the construction of certain lines is demanded by the port for the convenience of the public, and the railway administration has not considered it absolutely necessary, the administration requires the port to bear, in addition to the cost of the formation, the whole or part of the cost of the track.

In the latter case a special formula has sometimes been used. It consists in assuming that the port « advances » the cost of the superstructure until the day when traffic requirements will have increased to such an extent that the railway administration will recognise that the installation in question has become indispensable. When that date arrives the port is entitled to demand repayment of the « advance ». This procedure has been adopted recently at *Le Havre* and *Rouen*.

Finally, for certain schemes of a particular character the whole cost is advanced by the port, which contracts a loan for the purpose, the amortisation of the loan being secured by means of temporary local extra taxes.

CHAPTER II.

Tariffs.

All railways accord reduced tariffs to traffic from or to the ports which they serve. At first sight this policy would appear to be dictated by the desire to lower the net cost of production of national products and to enable them to find an outlet in markets abroad. This is not, however, the whole explanation, for it is a fact that in many countries the transport of goods from and to ports costs less than transport from and to neighbouring countries over the land frontiers. In the circumstances it must be admitted that the reduced tariffs applied to consignments from and to the ports of a country aim rather at attracting towards those ports the greatest possible volume of traffic, thereby attracting ships by the abundance of freights.

If the abundance of freights, whether entering or leaving a port, lowers freight rates and thus favours the development of the port, this is not the only effect, for it also encourages the importation of raw materials and the exportation of finished goods and, correspondingly, results in a constantly increasing railway traffic.

In Belgium, where the coastal areas are relatively small as compared with the land frontiers, the railway has to take practically no steps to defend itself, within the national territory itself, against competition by sea transport, for example, in the case of two ports which can be reached equally by rail or by sea.

In other countries which, like France, have a highly developed coastal traffic, railway tariffs are fixed with an eye to the competition which the railways may suffer from coastal shipping.

When, for any particular reasons (abundance of cargoes, cheap labour, geographical conformation of the interior, etc.) a port exercises an attraction beyond the boundaries of the country in which it is situated, the railway which serves that port adapts its tariffs to this situation. It would not be reasonable in such a case to adopt tariffs such as would counteract this natural attraction : their function is on the contrary to encourage it.

In Belgium, tariffs for overseas imports and exports are only applicable to consignments from or to public ports, *i. e.* ports which are open to all, to the exclusion of those ports which have been established by private parties for their own use.

Minimum tonnages are laid down for each particular case; in some cases it may be as low as 5 tons *per consignment*, whereas in others it may be as much as 300 tons or even a complete train load.

In other cases a minimum period is fixed (one month, one year).

Up to the present, except for loads known as « incomplete », *i. e.* less than 5 tons, Belgium has adopted no through tariffs with countries overseas.

On the French railways, consignments despatched by slow goods train for exportation, either through a port or through a frontier station, enjoy in general a reduction of 10 % in the tariffs (general or special) which are applicable to such consignments in the internal traffic of the country. In exceptional cases this reduction is even greater for certain goods, where it is desired to encourage their exportation; conversely, this reduction is not granted in certain cases when it is desired to retain such goods within the country for national consumption.

Further, for goods which require special traffic facilities, special export tariffs and regulations are applied which still further favour such goods.

In the case of *export* traffic, the tariffs are generally applicable with the same tonnage conditions as for internal traffic. With certain exceptions, specified in the tariffs, no account is taken of the place of origin of the consignments.

In the case of *import* traffic, certain special arrangements have been adopted to facilitate the transport of goods arriving from foreign countries.

⁂

In large ports, if special precautions were not taken, wagons might easily waste time between their arrival at the harbour station and the reaching of their final destination at the quayside.

In this connection, the port of Antwerp requires that waybills should bear the number of the quay or shed for which wagons are intended. Such a requirement may, however, present difficulties in the case of goods coming from distant countries. In this case, if the number of the quay or shed is not shewn, the frontier arrival station, immediately the train arrives on the Belgian railway system, despatches a telegram to the Antwerp station master giving the number of wagons, the nature of the goods, the names of the consignor and consignee, and the station of origin.

On receipt of this telegram the Antwerp office sends a special messenger to the address of the consignee with a request that the latter shall at once notify the number of the quay to which the consignment is to be delivered (1).

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(1) Where necessary, the advice is given by telephone.

On the arrival of the train, the station master immediately has it run to the appropriate quay, which operation does not therefore depend upon verification of the transport documents but upon the information given by the consignee.

These documents are sent by special messenger, immediately after the arrival of the train, to the marshalling station goods offices, which verifies them and advises the consignees of arrival.

Although the Belgian inland regulations allow of the running of several wagons on a single waybill, such a document is required for each wagon or group of wagons despatched to the same quay of the port of Antwerp, with a view to accelerating operations on arrival.

In order to place goods at the disposal of the consignee as soon as possible after arrival, several French railways adopt the practice of giving telephonic advice from the goods station marshalling yard, and despatching an advice note from the harbour station for express delivery to the consignee.

Demurrage charges.

The period fixed for the loading or unloading of wagons in the Belgian ports is « in principle » 8 hours, as in goods yards.

Shunting time is deducted. In the port of Ghent, for example, the period varies from 8 to 12 hours and from 14 to 18 hours.

A sliding scale of charges for excess periods is applied.

In the port of *Antwerp* the period for the *loading* of wagons is, as elsewhere, 8 hours, but there are special regulations with regard to *unloading;* a distinction is made between goods transhipped directly from wagon to ship and goods deposited on the quay to await arrival of the ship. These regulations, in particular, allow a period of 3 working days for goods transhipped direct from wagon to ship, subject to payment of a charge of so much per ton (1).

In the ports served by the French Nord Railway, the period for the loading and unloading of wagons is 6 hours. Penalties are imposed where this period is exceeded, but they are calculated per hour and not per period of 24 hours as is the practice in goods yards. Rebates are granted in certain ports when the time taken is less than 6 hours.

On the French Midi Railway, the regulations adopted in regard to the period to be allowed for the loading and unloading of wagons and to the application of charges for standing wagons are, in general, the normal regulations applying to general internal traffic.

In the port of Marseilles, the Paris-Lyons-Mediterranean Railway as a general rule allows 4 hours for loading and unloading. Charges for excess periods are calculated at so much per hour, with a maximum corresponding to the charge per day laid down in the general tariffs.

CONCLUSIONS.

We will not attempt to disguise the difficulty we experience in formulating conclusions with regard to the question under consideration. That difficulty is not, however, a reason for not making the attempt, even if it is merely to provide a basis for discussion at the Madrid session and to give experienced members an opportunity of expressing their views, which, indeed, may be directly opposed to our own.

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(1) Loose goods whose low value will not bear the cost of loading in two operations are treated in the same way as goods transfered direct from wagon to ship. The former goods represent 25 % of the total traffic of the port of Antwerp.

Further, these conclusions must necessarily be concise and must, therefore, be interpreted in the light of what has been said in this report :

1. — Wherever local circumstances or special considerations are not opposed to such an arrangement, it appears preferable that a port should be served by a single harbour station. In any case, the creation of several harbour stations can only be justified if the volume of traffic is such as to permit of the running of complete trains from the interior to each of these stations and from the stations towards the interior;

2. — Having regard to the interruptions experienced in port working, the installations of a harbour station must be conceived with a certain amplitude to allow for temporary cessation of activity within or without the port and to prevent this disturbing factor from extending to the railway system outside, and vice versa;

3. — There is no occasion to have separate stations for local traffic, through traffic and shipping traffic so long as the limit of capacity of the single existing station has not been reached;

4. — It seems preferable to concentrate all the shunting and sorting operations in the harbour station rather than to effect them in the vicinity of the quays, the latter system always entailing a reduction in output. The only shunting operations which should be effected at the quays are those which are required by the stevedores;

5. — The function of back-quay tracks is essentially that of holding loaded and empty wagons with a view to ensuring the continuous and rapid feeding of the quay tracks;

6. — Empty wagons to be used again within the port must only pass back through the harbour station if they can thereby reach their new destination more rapidly and more easily than if they were sent there via the quay tracks;

7. — Commercial considerations require the avoidance of the splitting up of consignments for export overseas, even at the cost of a certain sacrifice of good locomotive working;

8. — Although the configuration of a port (form and extent of its basins, etc.) is designed to afford facilities for the entrance, mooring and departure of ships, it is nevertheless desirable that the railway should be asked to express its views when plans are under consideration. Subject to ensuring the above-mentioned facilities, that configuration should be adopted which will allow of the most suitable railway installation (*i. e.* lines serving the quays and connecting lines between the quays and the harbour station) both from the technical and from the commercial point of view;

9. — The lay-out of the harbour basins should be planned in such a manner as, without interfering with the operations connected with the entrance, mooring and departure of ships, will allow of the provision of curves of sufficient radius (a minimum of 120 m. [6 chains]) for the connecting lines between the quays and the harbour station;

10. — From the point of view just mentioned, it is necessary not only that the quay spaces should be of a width proportionate to the width and length of the basins, but also that they should afford the railway adequate room for a lay-out of tracks which will ensure that rapid movement of wagons which is essential to commercial operations;

11. — Three tracks along the quayside, with intermediate connections, appears to be the arrangement which best meets requirements;

12. — In modern installations, turntable roads and sunk or surface traversers are being replaced by switches for connection between tracks;

13. — Quay tracks laid with guard rails or grooved rails in such a manner that the tread of the rail is level with the paved surface, thereby facilitating cartage and cleaning, constitute an interesting solution of the problem of providing for the simultaneous movement of railway wagons and road vehicles;

14. — *a*) At the quayside and for current it is rather the number of loading and unloading cranes than their capacity which is of importance. However this may be, we find that in modern installations the lifting capacity of these appliances varies from 3 to 5 tons;

b) The use of gantry cranes running astride several tracks is greatly to be recommended;

c) High capacity lifting gear is necessary, but the number of such appliances need not be great. They are indispensable for the service of special installations;

15. — As mechanical means of loading and unloading become more and more powerful, it is essential that the railway should take all possible steps to ensure a rapid movement of rolling stock to and from the quays;

16. — If a given class of traffic is to be attracted to any port on a large scale, it is essential that it should be allotted a special area within the port equipped with the appropriate installations.

17. — Tariffs applied to consignments to or from seaports are dictated by the desire to augment the natural attraction exercised by the ports.

Consequently, these tariffs are essentially variable, according to the circumstances of each particular case. Nevertheless, in the case of important streams of traffic, the reductions allowed are generally dependent upon fulfilment of certain conditions, producing a reduction of net cost : minimum tonnage per consignment, minimum tonnage within a given period, complete trains, daily or otherwise, etc.

621 .132 .8 & 656 .22]

REPORT No. 4

(Germany)

ON THE QUESTION OF ECONOMICAL TRACTION METHODS FOR USE IN PARTICULAR CASES (SUBJECT XII FOR DISCUSSION AT THE ELEVENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION) (1) (2),

by Mr. LEIBBRAND,

Director of the Deutsche Reichsbahn Gesellschaft (German State Railway Company).

Figs. 1 to 35, pp. 590 to 634.

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(1) This question runs as follows : « *Economical traction methods for use in particular cases, as for example* :

A) Organisation of train services on the minor lines of the large systems carrying little traffic, and of little used trains on the more important lines of these systems.

B) Use of special tractors for shunting in smaller yards and for certain work in large yards ».

(2) Translated from the German.

A. — Organisation of train services on the minor lines of the large systems carrying little traffic, and of little used trains on the more important lines of these systems.

Two distinct stages have in general marked the development of large railway systems. The main traffic arteries came into existence first, and only after the bulk of those were finished was the network completed by the construction of less important lines. This sequence is the logical result of economic facts. Enterprise and capital could be found easily and quickly for lines from which good traffic and, therefore, a safe and good revenue was to be anticipated. But there was no immediate inducement to invest capital in secondary lines which in themselves did not offer an adequate return. Some of the sparsely used lines were considered worth building and of financial value to existing undertakings because they were looked upon as feeders to the original system. Others owed their existence to general economic considerations which overrruled to a greater or less extent the question of whether they were individually profitable. The prosperous and highly developed areas having been provided with main line systems, the duty was imposed upon the State as the Railway Authority, of connecting up to the network the poorer and more backward parts of the country in order to obviate further impoverishment of that section of the tax payers.

In Germany the year 1879 may be looked upon as marking the division between the two stages of development. It was in that year also that Prussia decided in favour of the principle of State Railways. At that time there were in operation about 30 000 km. (18 640 miles) of main lines and only 3 000 km. (1 864 miles) of subsidiary lines; up to 1913 the aggregate length of all German main lines increased by about 1/6 only, to 34 700 km. (21 560 miles), whereas the secondary lines multiplied in the same period tenfold, with 26 500 km. (16 470 miles) of standard gauge and 2 200 km. (1 367 miles) of narrow gauge.

The progress which has been made on the large German railway systems in extending development proceeding from the large to the small has been very remarkable and of far-reaching importance for the economic working of the secondary lines. Ideas with regard to construction and operation, safety measures, staff requirements economical working, etc., were at first based solely on experience with lines carrying considerable traffic. This was exemplified in the working rules, the training of personnel and the building up of traditions; moreover, the statutory requirements concerning forms of construction and operation were in consequence drawn up entirely on the same lines as those for heavy traffic with its greater earning capacity.

Uniformly stringent requirements for construction, for safety and routine operation, resulted in the subsidiary parts of the network having to bear an economic burden which was unnecessary. It was not as a rule possible to counteract the inadequate revenue of those sections by specially high fares; to increase the tariff in districts that were in an economically weak position was fundamentally unsound.

Even after the adaptation of the statutory regulations to suit the changed conditions brought about by the addition of subsidiary lines to the main system, the great German railway networks still suffered from certain after effects of the developments outlined above. The larger the system the more difficult is it to make internal adjustments and to break away from tradition. Further, an extensive uniformly operated State railway system does not lend itself readily to the special consideration of individual sections so that their construction and operation are adapted to their importance.

Small private undertakings which operate only a self-contained line carrying a small amount of traffic, are less handicapped in this respect; they are much less tied by statute, by traditions and the demands of publicity; construction and operation can from the outset be made in every way suitable to the smaller responsibilities; there is more freedom in constructing the tariff schedule, and, therefore, the receipt side of the balance sheet is more adjustable, irrespective of the contributions and interest guarantees of those financially interested in the railway.

In Germany the statutory regulations were modified when it was recognised that the sparsely used lines could only be worked on an economic basis if they were built, equipped and operated on a more modest scale than the trunk lines. On the 1 July 1878, there came into force the Bahnordunug für Bahnen untergeordneter Bedeutung (Railway Order for subordinate lines), which was based on preliminary work carried out by the Association of German Railways and formed an extension of the « Policing of Railway Rules » of 1871. The latter which were the sole regulations in force up to that time, retain their validity only in respect of main lines. The Railway Order ameliorated especially the regulations concerning the supervision of level crossings and the inspection of the track. A maximum speed of 30 km. (18.6 miles) per hour was prescribed. Later ordinances relating to the construction and operation of the railways maintained the distinction between main and subordinate lines, and in the Railway Construction and Operation Order of 17 July 1928, which is authoritative at the present time for both types of lines, many of the requirements are modified in respect of secondary lines.

For the purpose of the present discussion on economical operation, the most important requirements of the Railway Construction and Operation Order are those relating to the closing and supervision of level crossings, maximum speed, brake equipment, working of home signals, safeguarding the junction points with the main track, train signalling system, and track inspection.

Whereas all crossings on main lines must be provided with barriers and supervised, the former may be dispensed with at crossings on secondary lines which are not much frequented, and no supervision of unprotected crossings is necessary if the speed of the trains does not exceed 40 km. (25 miles). In the case of crossings where there is considerable traffic, both barriers and supervision may be omitted if the train speed is reduced to 15 km. (9.3 miles) when passing the crossing.

The maximum speed laid down for secondary lines of standard gauge and with a sound road is 50 km. (31 miles), or in exceptional cases 60 km. (37.2 miles). The braking equipment has to be considerably more than on main lines, because of the shorter braking distance, 400 m. (437 yards) instead of 700 m. (765 yards). The former is prescribed on account of the incomplete signalling equipment, particularly the absence of distant signals. Home signals are necessary only at passing stations and generally only when the speed exceeds 40 km. (25 miles). Interlocking of the incoming points and signals is not required if the former are normally kept closed.

For speeds below 40 km. (25 miles) advising of the trains by telephone is permissible, but at higher speed they must be advised telegraphically as on main lines. Inspection of the track is required only three times a week on secondary lines as against daily on main lines. Further concessions are dependent upon the consent of the Minister of Transport. Thus, permission may be obtained to dispense with the operation of the home signal at cross-over stations and to use the telephone for train advising, even when the speed is more than 40 km. (25 miles) per hour; also, track inspection may be reduced to once weekly.

The requirements are such that the operation of secondary lines is not in all respects more economical than that of main lines. Constructional simplification is to some extent counter-balanced by increased operating expenditure. This is particularly the case in regard to the reduced maximum speed, which in many cases leads to increased running expenses, owing to the slower circulation of personnel, locomotives and rolling stock impairing the extent to which they are utilised. The higher standard of braking called for does not affect the Reichsbahn so much since the introduction of the continuous brake on freight trains. Except in a few exceptional cases on secondary lines having specially severe gradients, the required proportion of brakes is always available.

The individual State Railways of the old regime set up at an early date, within the borders of the statutory requirements, certain principles and instructions for simplifying the operation of secondary lines, and thus freed them from the expensive main line system of working; they were impelled to do this by the rapid increase in the proportion of economically poor routes within their networks. They also endeavoured to reduce their expenditure by certain technical measures such as the introduction of cheaper methods of hauling.

When the whole of the German State Railways were incorporated in the Reichsbahn the undertaking was faced with heavy financial responsibility, and the question of cheapening the operation of secondary lines then became merged with many other large economic problems. The existing measures and experiences were carefully scheduled and supplemented by further proposals. The result of these investigations was embodied in certain guiding principles for simplying the operating and clerical services of secondary lines. The leading idea was to economise in personnel by certain measures of organisation. As in other important industries the wages bill of the Reichsbahn has increased enormously compared with pre-war figures; in 1928 it was 66.5 % of the total expenditure as against 61.2 % in 1913. This occurred in spite of the introduction at much capital expenditure of many measures directed towards reducing staff; the introduction of continuous brakes on freight trains alone resulted in an economy of about 30 000 employees.

Special prominence must be given to measures of re-organisation in that they do not, like the adoption of technical improvements, necessitate that considerable capital outlay, which means high rates of interest and prejudices the benefits that can be derived.

Out of the 53 750 km. (33 400 miles) comprising the network of the Reichsbahn about 23 450 km. (14 850 miles) are secondary lines. The great extent of the latter renders it possible to save really considerable sums by means which do not in themselves appear important, and consequently full advantage has been taken of the smallest possibilities of effecting economy.

In setting up their new guiding principles the Reichsbahn was bound to take as a starting point the fact that with light traffic neither the train nor station staffs are fully occupied. The total amount of work to be done is much smaller than the total capacity of the staff appointed to do it. The train staff is often idle whilst the train is standing at a station and similarly the station staff in the intervals between trains. The actual working time is usually so short and the idle intervals are so long that 8 hours work per day cannot be made up out of journey duty or station duty alone especially in view of the fact that the Reichsbahn regulations governing working hours limit strictly the duration of each shift. For example, shifts of more than 14 hours for station staff must not be worked more than 4 times in 7 days, even if the duty really consists only of preparation and intervals, and the duration of the remaining shifts may not exceed 12 hours.

More economical distribution of duty with an appreciably better use of the personnel and a correspondingly valuable saving in working secondary lines, results by making the train staff undertake wholly or partly the local duties while a train is standing in a station. The station staff is then either withdrawn entirely or at least very much reduced. The amount of traffic at individual stations and the number of trains determines to what extent it is possible to attain the ideal of working without any station staff at all.

The necessary conditions for the transference to the travelling staff of the station activities are the elimination of all work that is not absolutely necessary, and the utmost simplification of the whole routine of duty. Only by such measures is it possible for the train staff to carry out their duties reliably and punctually, and to ensure complete safety and the avoidance of station halts becoming longer than is permissible. In this connection it is worthy of special note that in consequence of the introduction of continuous brakes on the National Railway, even freight trains seldom carry more than two trainmen, a conductor and a guard. Obviously, even under the most thorough scheme of simplification it is not possible to do without a permanently located controller at stations where many trains and a great deal of shunting have to be handled.

At stations without permanent staff, described briefly as « unattended stations », the train conductor takes over the superintendence, shunting, and train movement control. Such stations continue to be the ends of block sections insofar as this is necessary for maintaining the time-table and the capacity of the track; in all other cases routine is simplified by relieving them of this function.

Traffic control on lines where there are unattended stations is taken over by certain attended stations called « train control stations ». A train-control station may either be allotted one section with a contiguous unattended station, or its area may be extended to a whole group of stations some of which may be attended stations. If the whole of the operating staffs are withdrawn from every station on a secondary line, the duties of train control are undertaken by the station at the junction with the main line. The official responsible for regulating the train services in the districts controlled by a train-control station is called the « Zugleiter » or « train controller ».

The train-control station arrangement may be considered as a very much simplified despatching system, in which the special circumstances allow costly technical auxiliary apparatus to be dispensed with; the track and stations are shewn in the controller's office on a simple wall chart, on which the positions of the trains can be continuously indicated by coloured balls moving on metal bars. The chart is also constructed in a transparent form, figure 1. To facilitate observation the two directions are shewn separately. The occupied section is illuminated by electric lamps, which are switched on and off by the train through simple rail contacts. No special electric conductors are necessary, as use is made of the existing telephone wires without, however, affecting their use for conversation.

Fig. 1. — Train-in-section chart for a secondary line.

The train conductors report the train movements to the train controller from the unattended stations by telephone and receive their instructions from him. The conversations relating to traffic are entered by both parties, in the usual way, in train advice books, telephone books, etc. Passing and overtaking is dictated by the train controller and the instructions are entered by the train conductor on a prescribed form.

The extent of train advising is substantially less than with the routine previously in force on the Reichsbahn. It is not necessary to offer the trains, as on other single-line sections, so long as the scheduled train sequence is adhered to. Reporting back can be omitted, provided the next train runs in the opposite direction, and, therefore, also when only one train set is running on the line. In routine working, therefore, only the departure of trains is signalled. The complete advisory system is only carried out in the case of special trains, and abnormal crossing and overtaking, and is restricted to the trains immediately concerned and the section between the normal and the special crossing or overtaking point.

Generally speaking a train may start towards an unattended station only when it is certain that the previous train has cleared the end of the second block section ahead.

The reason for this unusual caution in

the train control is the risk that after a train conductor has reported to the station in his rear that he is starting, something may suddenly occur at the last moment to prevent him going on. The succeeding train would then follow on in ignorance of the fact that this track into the station had not yet been vacated by the preceding train.

If the double station interval leads to irksome complications of the time table, it is permissible to run the trains with a single interval. Safety is then ensured by special precautions. Where a second arrival line is provided, the arrival points for the following train must be opened by the conductor of the first train before signalling his departure; if there is no second track care must be taken to safeguard the standing train. The most effective method is by using a stopping disc situated at an adequate distance from the arrival points and illuminated at night. The disc is remote operated so that it can be brought into use as quickly as possible. In no case has difficulty occurred in train control with single station interval.

Crossing at unattended stations requires special attention. The scheduled sequence of arrival of the two trains is always adhered to, even if the first train is delayed and arrives outside the station after the second one. The conductor of the first train takes over control on arrival and brings in the second train which has to stop outside the station at a definitely indicated spot. He looks after the safety of the passengers when the second train draws in.

Any other train may draw into an unattended station without previously stopping if the train staff is quite satisfied that the points are correctly set. Information as to the position of the points is given by the train controller, when he gives the order to proceed, in accordance with the advice he has received from the previous train. If necessary the arrival track must be set by the train staff.

The arrival signals are not operated at unattended stations even for running speeds of more than 40 km. (25 miles) an hour, the necessary consent of the Minister of Transport having been obtained for this deviation from the regulations.

The greatest care must be taken to regulate the operation by the train staff of the points for running and shunting, in order to obviate undesirable stopping of trains on arrival and departure, and loss of valuable time through undue movement of the staff in the station.

Centralised control of the points is not expedient from the point of view of simplified methods of working; if it were used it would necessitate the train staff having to proceed from the end of the station to the control point to arrange for an arrival or departure or the taking off or adding of a coach. It must be possible for the train-man who is attending to the shunting to set the points himself on the spot. For this reason any control levers existing at unattended stations have been disconnected.

Further, the crossings on secondary lines are in many cases very long, that is to say, the points are far apart. Where the limited financial resources permit, a new set of points is put in, one of the existing sets being disconnected, and by this means the distance for shunting and operating is reduced.

Loss of time and train stops at crossing points in stations can also be avoided by arranging the schedule of running so that a train runs in on the same road used by the previous train in the oppo-

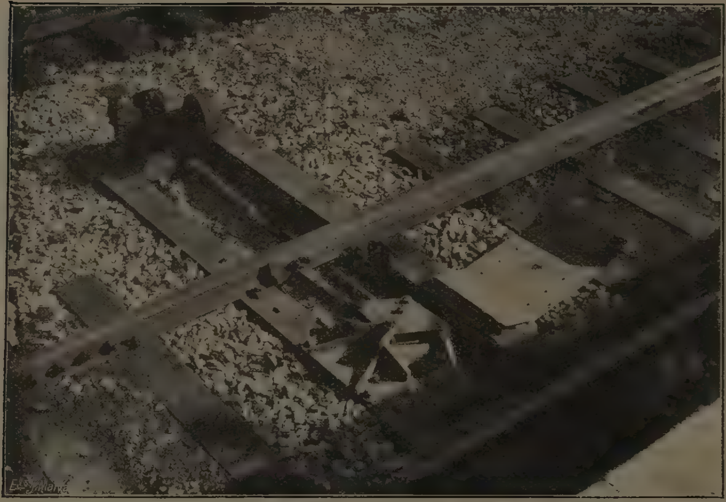

Fig. 2. — Automatic return points.

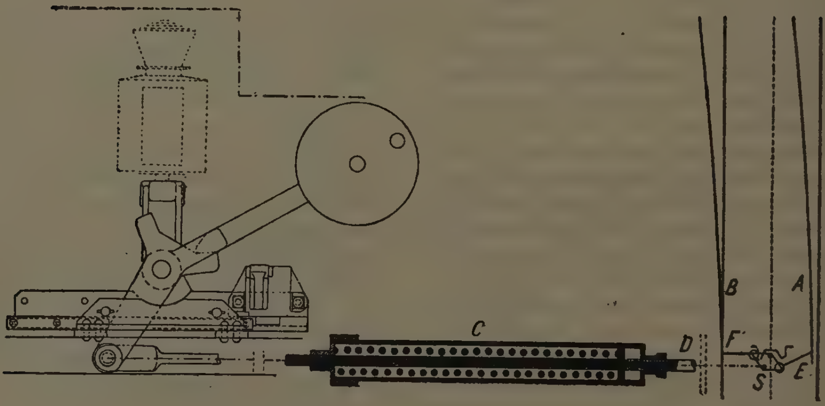

Fig. 3. — Automatic return points. — Details.

site direction. The track used thus alternates at each crossing systematically.

The correct setting of the pairs of points for train crossing can also be ensured without additional work by interconnecting them mechanically so that they always set the route to different tracks. Such interlocking, however, ne-

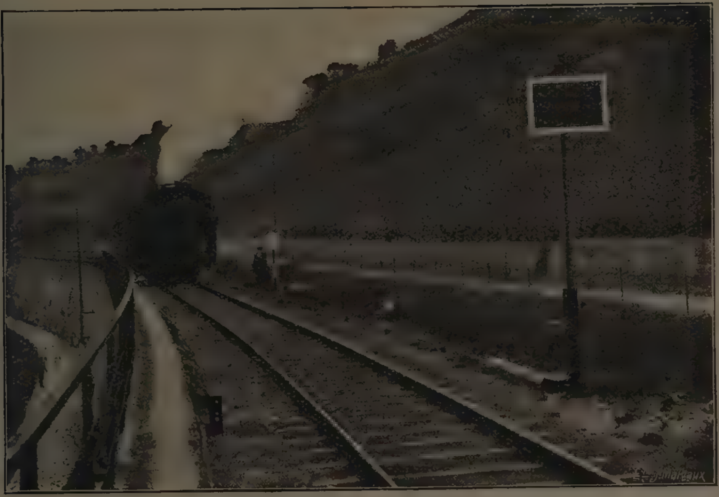

Fig. 4. — Stopping disc in « Stop » position during the opening of the points.

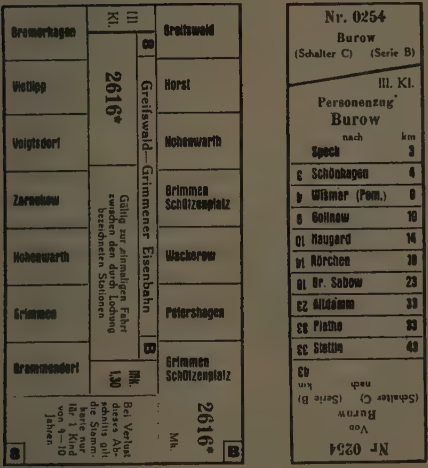

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Fig. 5. — Zone tickets and stage tickets.

cessitates operating them together from one position and the disadvantages of central point control from the point of view of simplified operation have already been discussed.

A type of point that is very serviceable for the same purpose is the automatic return point which is opened by the outgoing train and then returns to the normal position so that an incoming train is always fully safeguarded. Figure 2 shows the general arrangement and figure 3 the details of the points with return spring and toggle lock. An electrical indicator shows the position at the station or to the train controller, utilising the existing telephone wires in such a way that no disturbance is caused to simultaneous conversation. A signal disc is connected to the points in such a way that it turns to the « stop » position if there is any gap however small between the point tongues and the rails. Figure 4 shows the « stop » position during the opening. Such points are traversed at speeds not exceeding 20 km. (12.4 miles) per hour.

The safety of hand-operated points at unattended stations is ensured by a hand lock. They are opened by a train-man as required after the arrival of a train and set again in the prescribed position before departure. The keys are handed to the train controller at the end of the trip and given out again by him as required.

The limitation and simplification of local operating duties call for corresponding measures in the traffic duties.

Passengers from unattended stations purchase their tickets in the usual way from the conductor during the journey. Zone tickets and stage tickets, figure 5, are used. The zone tickets have printed against the names of the various stations all the connections of the line for which the printed fare is the same. The stage tickets are separated underneath the destination as issued, and the severed portion serves for checking. Luggage is accepted at the brake van by the conductor and has to be fetched from there by the passengers. The weight is judged or ascertained on the weighing apparatus that is carried. Express goods are dealt with in a similar way.

Unattended stations are still retained as tariff stations for freight traffic. Cattle and consignments generally are restricted to what can be loaded and unloaded without special arrangements, any other freight being subject to special negotiations from case to case.

Wagon-loaded consignments are put on to the train from the loading road by the conductor and the contract for conveyance of the goods is only valid after acceptance by him. In the case of consignments detrained at unattended stations, the conductor stamps the way-bill, advises the consignee by postcard, places the packages in the goods shed or hands them over to the owner, and puts the wagon into the loading bay. When the consignees do not attend, the conductor retains the way-bills and hands them over to his relief at the end of the shift.

It is clear that this arrangement requires that those making use of the goods service shall co-operate. The sheds are locked up by the conductor before proceeding. There is no greater risk of theft than was formerly the case at stations left unattended at night.

Acceptance and delivery of corpses is limited to stations where there are facilities for loading into wagons.

The conductor can deal with freight charges on the basis of the rate schedules for local or through traffic. When transhipment is necessary he calculates only for his section of the journey, or if necessary enquires by telephone at a junction; otherwise he makes a covering charge.

For accounting purposes he keeps returns of passenger tickets, luggage and express goods, and a way-bill number book and charge tickets for outward and inward packages. A cash receipt is made out for all money taken and the latter is entered in a cash book with which the vouchers are kept.

The whole of the accounting and bookkeeping for the conductor's business is dealt with by a particular station, the « mother station ». The accounts are kept separately for the individual unattended daughter stations.

The orders for wagons and their number are reported to the mother station by the train conductor.

In spite of every simplification the despatching operations make great demands on the knowledge and capabilities of the conductor. When a great deal of business has to be transacted most undesirable delays in the scheduled stops are unavoidable with dislocation of the time table and its resulting troubles. The circulation of staff, locomotives and coaches can become so badly affected by the longer stops that a considerable part of the economy aimed at in station duties is sacrificed again. The public does not take at all kindly to the curtailment of the time given to them by the conductor. Hence, the handling of the traffic by the train staff is only really expedient in the case of quite a small amount of freight traffic. If there are more than about five way-bills at an unattended station only the service operating duties can be attended to by the train staff. Some other means of dealing with the despatch details has to be found, of which the first to be considered is the appointment of agents.

The person selected for this post is one of the local inhabitants and he is not a railway employee in the strict sense. He is usually engaged in some business as the principal means of livelihood, such as an innkeeper, a merchant, carrier, etc., with which he can easily combine his railway duties as a side-line. Or he may be a retired railway servant to whom additional income is very welcome to supplement his pension. The agents undertake their duties on agreed terms which are considerably less than the pay of the railway officials who were previously necessary, and their recompense sometimes consists wholly or in part in giving them living accommodation in railway property. The pay accorded depends upon the number of tickets sold, way-bills completed, etc., in fact, on the volume of business transacted and not on length of service. Since the agent may be represented at any time by his relatives or even his employees, no question arises of length of service or of compliance with the rigid code relating thereto. He is not continuously on duty at the station, but is usually available to the public at his private occupation.

It is not generally advisable to tranfer to the agents any matters concerned with safety of operation, since the question of length of service then arises, which in turn is closely bound up with that of working safety, and difficulties would be created in the agent being deputised for by members of his family. In addition to the agent it would also be necessary to engage reliefs for long shifts, Sundays, holidays, etc. Any economic advantages would be quite neutralised.

It is, therefore, essential to divide the activities of an unattended station, so that the agent deals with the traffic and the train staff with the local operating duties.

Moreover, when agents are employed it is essential that the traffic business shall be arranged in as simple a manner as possible, since the agent has not usually as good an education as the railway officials, and his hours of duty must be kept to the minimum, in order to reduce expenditure. For these reasons the system of mother and daughter stations is adopted. In this way the fully staffed mother station takes over the whole of the work of keeping the accounts of the daughter stations. All the service correspondence with the agent is done through the mother station.

The agent's periods of attendance are kept as short as possible, the ticket and luggage booking-office being opened only a quarter of an hour before the time of the departure of the train. For early and late trains the requirements of passengers, luggage and express goods are taken over by the conductor so as to reduce the agent's working time.

In cases where the employment of agents would lead to difficulties, a third method of splitting up the duties has proved satisfactory.

Freight business is handled by a travelling railway official, who is sent to the unattended station from some other point for one or two hours each day; the tickets, luggage and express goods are dealt with by the train conductor. The hours during which the travelling official attends are arranged in accordance with the time table and are advertised. Packages and way-bills for trains outside his hours of attendance are placed by the travelling official in lock-up sheds from which they are fetched by the train conductor. Conversely the conductor deposits incoming consignments in the sheds. Wagon shipments are prepared by the official only, and are taken away by the conductor during the unattended period.

It is not necessary to limit the facilities for despatch from a station at which an official attends only at certain hours. The travelling official accounts to the mother station for all the daughter stations he represents.

The above-mentioned systems do not exhaust the possibilities of economising in permanent station staff. The wide variety of conditions met with in the extensive network of the Reichsbahn affords scope for many other contributory factors which vary in their details. Since the underlying idea is the same in all cases, further consideration of them may be omitted.

The opportunities of economy on the trains of the Reichsbahn are inherently much fewer than in the case of station duties. As already stated, the introduction of the continuous brake on freight trains has effected a general reduction of the train staff to a very low level. A freight train with no more than 60 axles or 30 wagons does not usually carry more than the conductor; in any case, trains with not more than 30 axles or 15 wagons no longer carry a train-man in addition, provided he is not necessitated by loading and unloading duties, shunting or other work at wayside stations, like the routine work already outlined for unattended stations. The brake van which is usually placed immediately behind the locomotive is placed at the tail end when a conductor only is carried, so that he can look after the safety of the train without loss of time in the event of unforeseen stoppages. Further, if no conductor is carried, the driver takes over the conductor's duties.

As a rule entire freight trains are not run on secondary lines with very little traffic. Composite trains for passengers and goods traffic are the rule, provided the stopping period necessitated by goods does not interfere with the passenger traffic or prove detrimental to the circulation of staff and rolling stock. Lengthy journey times are particularly undesirable in cases where they would encourage still further the ever-increasing competition of road vehicles. The running of separate passenger and goods trains is an economical proposition if it is possible thereby to improve the time table and the allocation of duties to such an extent that no addition is required to the number of locomotives or staff, in spite of the greater mileage worked by both. Whether this is possible or not can be ascertained easily by examining each case on its merits.

The deciding factor is the maximum speed that is permissible on the route. Within the speed limit of 60 km. (37.2 miles) specified for secondary lines, the effect of speed upon coal consumption is of negligible importance. If, therefore, higher speeds do not bring about increased expenditure in other directions, the resulting improvement in the utilisation of staff and stock is practically a clear economic gain. At speeds of the order now in question, the increased cost of construction and maintenance is not of much account, but the supervision of level crossings is another matter. The regulations of the Railway Construction and Operation Order already referred to make the Reichsbahn responsible for deciding whether the speed shall be reduced to 40 km. (25 miles) or even 15 km. (9.3 miles) an hour, or whether a gate or barrier shall be erected, depending upon the volume of traffic using the road and the field of vision. To what extent the modern development of traffic calls for amendment to the regulations concerning the supervision of crossings, and whether limiting the speed of trains is capable of increasing safety at these points, are much debated questions in Germany also, and it is not proposed to discuss them here. The operating arrangements on secondary lines can only be based on the regulations now in force.

Speed losses resulting from the unwatched level crossings, or maximum speeds of 60, 50 and 40 km.
(37.2, 31 and 25 miles) per hour.

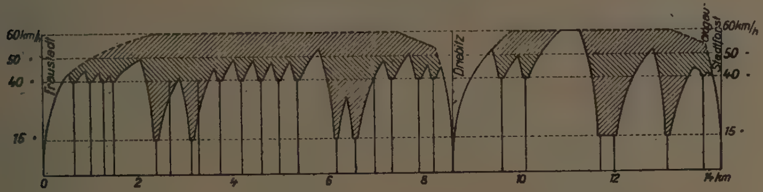


Fig. 6. — Speed-distance chart of a passenger train on a secondary line.
(Fraustadt-Glogau-Stadtforst).

The cost, incidental of the use of barriers, is so high that unless they can be arranged for remote operation from some other point, it is generally preferable on lines with little traffic to stipulate a reduced speed when passing over crossings. This has been rendered much easier by the introduction of the continuous brake on freight trains, since more powerful and reliable braking is thus available than in the days of the hand brake. The braking period can, therefore, be much shorter than formerly. If, however, there are only short intervals between the crossings it is either totally impossible to speed the train up to a maximum of 50 km. (31 miles) or 60 km. (37.2 miles), or that speed can only be maintained for such a short distance that no appreciable saving of time is effected.

The adoption of a higher maximum speed than 40 km. (25 miles) then becomes useless and uneconomic.

Therefore, the relation between train

speed and crossing supervision requires to be accurately investigated for each particular section. The best way of doing this is to use speed-distance charts which show clearly the effect of each crossing; an example is shewn in figure 6. The section is about 14 km. (8.7 miles) long and contains 25 crossings, of which seven may be traversed at 15 km. (9.3 miles) per hour and the remainder at 40 km. (25 miles) per hour, without supervision being necessary. The height of the hatched area corresponds at each point to the loss of speed, due to observing the crossings. Table I shows a comparison between the average speeds and the journey times for maximum speeds of 40, 50 and 60 km. (25, 31 and 37.2 miles) per hour, with and without supervision of the crossings.

TABLE 1.

Influence of crossing supervision on journey time.

Crossing.	Maximum speed V_{max}. Km. (miles) per hour.	40 (25)	50 (31)	60 (37.2)
Without watchmen.	Average speed V Km. (miles) per hour.	35.49 (22.05)	38.39 (23.85)	38.69 (24.04)
	Journey time T . . . . Minutes.	24.1	22.2	22.1
With watchmen.	Average speed V Km. (miles) per hour.	39.08 (24.28)	47.78 (29.69)	55.41 (34.43)
	Journey time T . . . . Minutes.	21.8	17.9	15.4

If by using watchmen at the seven crossings for which otherwise the speed would have to be 15 km. (9.3 miles) per hour, a speed of Vmax. = 40 km. (25 miles) per hour were maintained, a saving of 2.3 minutes would be effected. If all 25 crossings had watchmen and a speed Vmax = 60 km. (37.2 miles) per hour was observed, the saving would be 6.7 minutes.

It can be seen that each minute saved has to be paid for very dearly in barrier supervision, and, therefore, that it is never justifiable economically to employ special watchmen at each of numerous crossings on a little-used line. Every opportunity must be taken, therefore, to arrange for barriers to be attended to from neighbouring points without increasing the staff. In all suitable cases the agent can co-operate in the duty of closing barriers.

As compared with the economies that can be effected in station and forwarding duties and in the supervision of crossings, those that are possible on the locomotive side are usually more modest. It is true that in the case of the locomotive staff, as in that of the train staff, certain local duties can be undertaken, under straightforward circumstances, during the time when the locomotive does not require their attention. These comprise coaling, cleaning fire, washing out and heating up the locomotive, pumping water and minor maintenance jobs. But unfortunately these tasks are seldom required at the intermediate stations where the time is available. In special cases the fireman is made to assist regularly during the stop at a station, with shunting, coupling, point movements, loading and unloading, etc. No part is taken, however, in signalling or sending off passengers or goods.

The most effective measure of economy in locomotive operation is to employ only one man for locomotive duty. Actually the Railway Construction and Operation Order prescribes that steam locomotives shall as a rule have two men on them, even on secondary lines. Nevertheless, it is permissible for a train-man to travel on the locomotive instead of the stoker, thereby doing away with the latter. Generally speaking advantage is not taken of this possibility because if the conductor travelled on the locomotive as mate, he would be seriously hampered in carrying out his own duties, particularly the sale and checking of tickets and keeping his journey report and statistics. The solution adopted by a group of Reichsbahn Divisions, in particular by the former Bavarian system, was to construct special locomotives for the secondary lines arranged with a connecting gangway giving access to the first vehicle so that the train conductor is able to visit the locomotive at any time on the journey and then obviate the necessity for a second man. An elevated hopper facilitates the firing and greatly eases the driver's work. Figures 7 to 11 show the peculiar arrangement of the locomotive. The service weight is 22.1 t. (21.7 Engl. tons), the coal capacity 0.6 t. (1 322 lb.), the maximum speed 50 km. (31 miles) per hour; on the level it hauls a train weighing 390 t. (384 Engl. tons) at a speed of 30 km. (18.6 miles) and on a 1 in 100 gradient 175 t. (172 Engl. tons) at 15 km. (9.3 miles). No more of this type of engine for one-man operation have been put in hand since 1914, because they are not powerful enough for the growing train weights. But this does not imply in any way that the idea has been dismissed as useless. Greater hauling power will have to be obtained in new designs with still more complete simplification in working, and automatic stopping in the event of the driver becoming suddenly incapacitated.

On electric locomotives the principle of carrying a second man has been abandoned insofar as the haulage of freight trains is concerned. The conductor has a place on the locomotive with provision for carrying out his various duties. This feature is not, however, peculiar to secondary lines.

A large number of motor coaches is in use for passenger services on lines where the traffic is light. Careful selection is made of the somewhat infrequent instances where the traffic conditions of a secondary line hold out a prospect of economic success. The motor coach has no easy task to hold its own in competition with a light steam locomotive. The locomotive being equally suited to passenger and freight service as well as shunting, is more generally useful and permits of more economic sub-division of duties than the motor coach. The latter only works with freight wagons in exceptional cases, and then only with a few, so that it can hardly ever replace the locomotive altogether, and cannot, therefore, wholly eliminate expenditure on locomotives.

The capital charges and maintenance costs of motor coaches are higher than

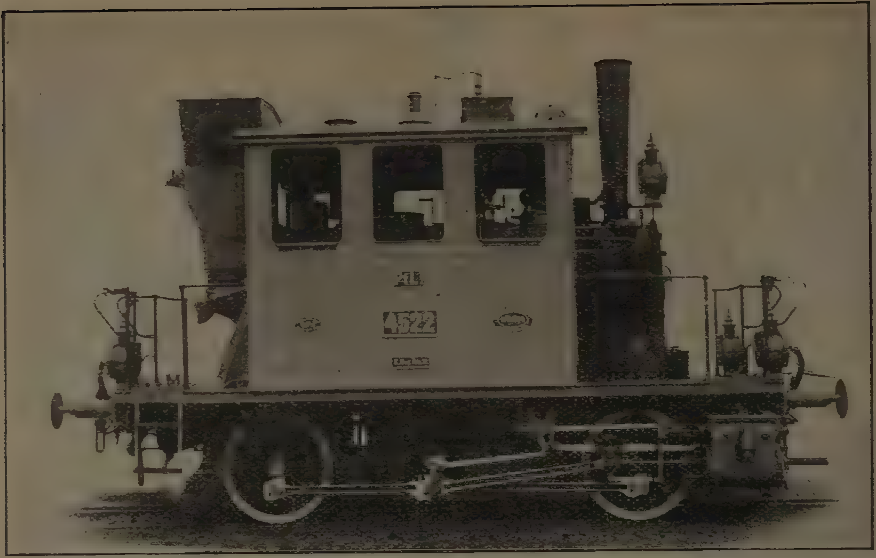


Fig. 7. — One-man locomotive for secondary line.

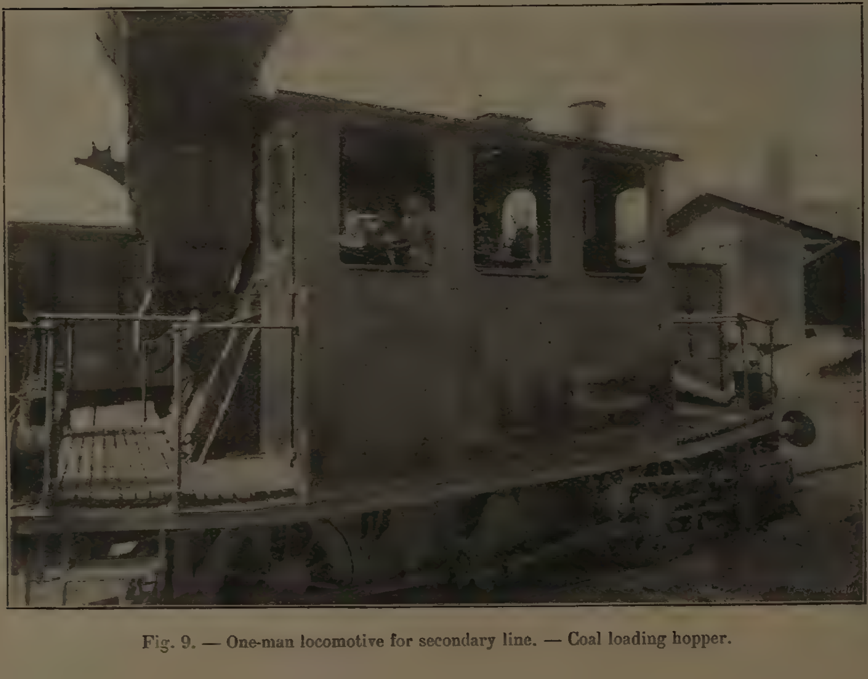


Fig. 9. — One-man locomotive for secondary line. — Coal loading hopper.

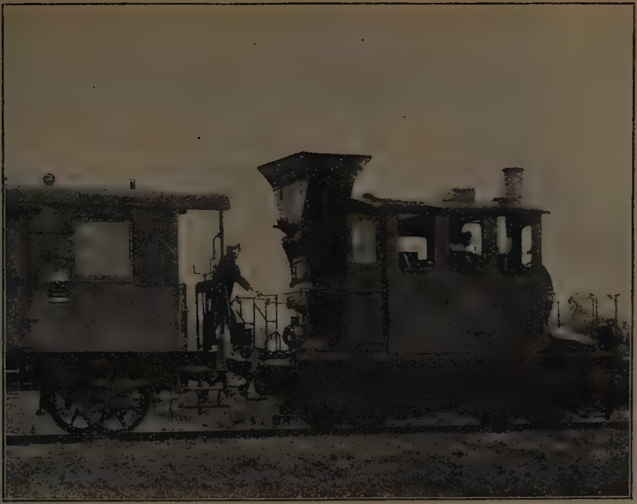


Fig. 8. — One-man locomotive for secondary line. — Gangway between train and locomotive.

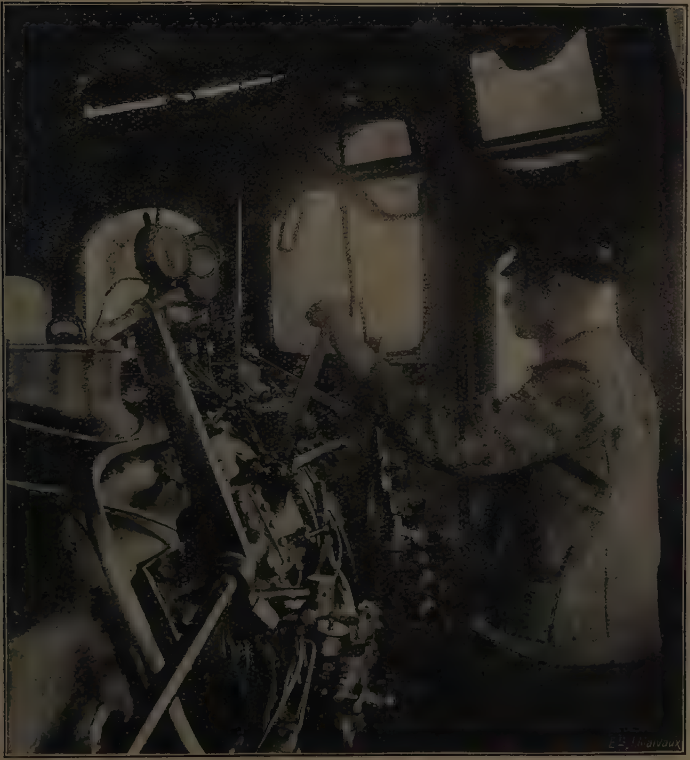


Fig. 10. — One-man locomotive for secondary line. — Driver's cab.

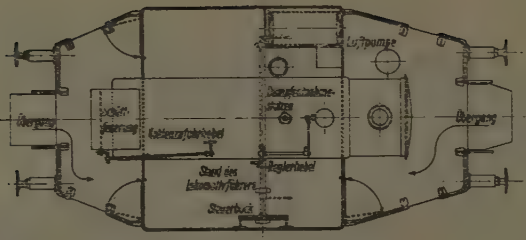


Fig. 11. — One-man locomotive for secondary line. Diagram.

Explanation of German terms: Dampfentnahmestutzen = Steam drawing pipe. — Kohlenzufuhrhebel = Coal guiding lever. — Luftpumpe = Air pump. — Reglerhebel = Regulator lever. — Schüttfeurung = Firing by gravity. — Stand des Lokomotivführers = Driver's place. — Steuerbock = Reversing gear frame. — Uebergang = Gangway.

those for a steam locomotive of the same power. Only when very full use is made of motor coaches can this disadvantage be compensated for by the shorter time required for starting up ant putting away the economy effected in staff, and to some extent the smaller consumption of fuel and stores. Only in exceptional cases does the time table of little-used lines allow a high daily average output to be attained. Table 2, which is based on experience obtained on the Reichsbahn, shows the relative positions very clearly.

It is seen that at the high daily duty of 200 km. (124 miles) on which the table is based, the motor coach train and the locomotive train are almost equal; the motor coach is superior when only a small seating capacity is required. If, however, trains are required with more trailer wagons than shewn in the table or if the figures are taken for lower daily duty than 200 km. (124 miles), the economic superiority of the motor coach very soon disappears. As the daily duty declines not only do the capital charges and the maintenance costs send up the costs per kilometre for the motor coach, but the advantage of a reduced wages item diminishes directly it becomes necessary to retain the staff for only one shift instead of two.

It is evident from calculation, and from the fact that 200 km. (124 miles) daily running can only rarely be reached, that in its present form the motor-coach does not offer any effective means of cheapening the working of secondary lines on the Reichsbahn, especially as there exists a surplus of steam locomotives for which additional capital charges do not have to be borne when new trains are put into service. This factor is of outstanding importance in view of the high rates of interest which have to be paid in Germany. Nevertheless, the rapid progress that is being made in technical development or a cheapening of capital may at any moment cause the position to alter in favour of the motor-coach.

Figure 12 gives a picture of the financial results of re-organising the operation of secondary lines by transferring the local operating duties to the train staff and the forwarding duties to agents in accordance with the principles previously outlined. The example selected

TABLE 2.

Comparison of working costs for rail motor coaches and light steam trains on passenger traffic.
Average daily mileage on level track : 200 km. (124 miles).

			RAIL MOTOR COACH.				LOCOMOTIVE.
	A. — **Costs for rail motor coach or locomotive without trailers.**						
1	Motors, number and type		2 Petrol.	1 Diesel.	2 Diesel.	2 Eletric.	Superheater.
2	Horse power		2-90	2-75/90	1-75/90	2-105	450
3	Source of power		Petrol.	Oil.	Oil	Accumulator.	Coal.
4	Fuel costs	Rm./ton	320	120	120	...	28
	Current costs	Rm./kw.-h.	...	...	...	0.08	...
5	Weight	tons	39.8	39.5	19.7	69	45
6	Speed	km. per hour	50	50	50	50	70
7	First cost	Rm.	98 000	100 000	55 300	137 000	63 000
8	Seats + standing room	Total	76+49=125	92+42=134	46+14–60	106+88=194	...
9	Staff, 2 shifts	Unit	2	2	2	2	4
10	Interest	Rm. per annum	6 860	7 000	3 871	9 590	4 410
11	Depreciation	—	5 960	6 000	3 606	1 990	1 890
12	Maintenance	—	9 800	10 000	5 530	6 850	4 725
13	Shed expenses	—	2 250	2 250	1 800	2 700	1 800
14	Accumulators	—	...	...	...	10 950	...
15	Total capital charges (10-14)	—	24 870	26 050	14 807	32 080	12 825
16	Capital + maintenance charges,	Rm. per km.	34.06	35 68	20.28	43.22	17.57
17	Wages	Rm. per annum	10 488	10 488	10 488	10 488	17 800
18	Wages	Reichspf. per km.	14.37	14 37	14.37	14.37	24.38
19	Fuel or current	—	13.66	4.5	2.69	11 20	7.90
	B. — **Extra cost for 1 trailer to accomodate 76 passengers ; weight 16 t.**						
20	Capital + maintenance charges	Rpf./km.	5.59	5.59	5.59	5.59	5.59
21	Fuel or current	—	3.88	1.26	1.26	2.86	1.21
22	Accumulators	—	...	...	...	7.50	...
23	Total (20-22) for 1 trailer	—	9.47	6.85	6.85	15.95	6.30
	C — **Total cost per kilometre without and with trailers.**						
				Without trailer.			*With 1 coach*
24	Total costs	Reichspf. per km.	62.09	54.55	37.34	68.79	56.65
25	Costs per 100 places	—	49.67	40.70	62.23	35.46	74.10
				With 1 trailer.			*With 2 coaches*
26	Total costs	—	71.56	61.40	44.19	84.74	63 45
27	Costs per 100 places	—	35.60	29.24	32.49	31.38	42.45
				With 2 trai ers.			*With 3 coaches*
28	Total costs	—	81.03	68.25	..	100.69	70.25
29	Costs per 100 places	—	29.24	23.86	...	29.10	30 78
				With 3 trailers.			*With 4 coaches*
30	Total costs	—	90.50	75.10	...	...	77.05
31	Costs per 100 places	—	25.63	29.77	...	...	25.32
				With 4 trailers.			*With 5 coaches*
32	Total costs	—	...	...	...	...	83.85
33	Costs per 100 places	—	...	...	...	...	22.04

TABLE 3.

NAME OF STATION.	KIND OF SERVICE.	Daily traffic.			Staff employed				Increase or Decrease in costs, Reichsmarks.	
					formerly		now			
		Tickets.	Luggage, express goods, packages.	Wagons loaded.	Full units + working days.	Annual costs, Reichsmarks.	Full units + working days.	Annual costs, Reichsmarks.	+	—
Bitburg	Terminus.	No alteration.								
Masholder	Not end of block section.	...	...	...	...	...	...	...	...	...
Messerich	End of section.	...	...	...	1+244	7 042	1 agent.	1 200	...	—5 842
Wolfsfeld	End of section.	...	..	...	1+244	8 042	1 agent.	1 620	...	—6 422
Niederweis	Not end of block section.	...	...	...	1+234	5 951	1 agent.	1 200	...	—4 751
Irrel	Train control station.	...	...	...	4+284	19 681	6+038	26 401	+6 720	...
Menningen	End of section.	...	...	...	...	...	...	...	...	...
Edingen	End of section.	45	7.2	0.5	1+078	4 520	1 agent.	1 080	...	—3 440
Ralingen	End of section.	41	5.6	1	1+240	7 006	1 agent.	1 080	...	—5 926
Wintersdorf	End of section.	31	5.3	1	1+078	5 281	1 agent.	1 080	...	—4 201
Metzdorf	End of section.	21	3.2	0.5	1+234	5 951	1 agent.	960	...	—4 991
Mesenich	End of section.	46	7.1	1	1+240	7 006	1 agent.	1 320	...	—5 686
Igel	Train control station.	No alteration.								
	Totals.	184	28.4	4.0	13+876	70 480	14+038	35 941	+6 720	—41 259

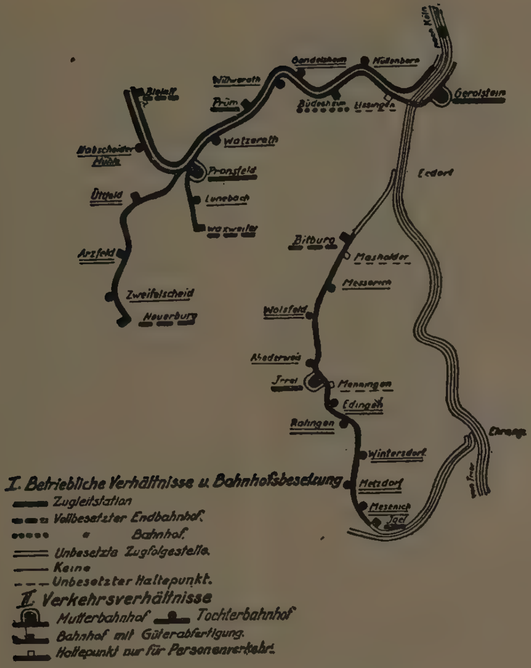


Fig. 12. — Secondary lines in Trier District.

Explanation of German terms:

I. *Betriebliche Verhältnisse u. Bahnhofsbezetzung* = I. *Operating conditions and staff in stations.*

Zugleitstation = Train-control station.
Vollbesetzer Endbahnhof = Fully staffed terminal station.
Vollbesetzer Bahnhof = Fully staffed station.
Unbesetzte zugfolgestelle = Unguarded end of section.
Keine = No end of section.
Unbesetzer Haltepunkt = Unguarded train stopping place.

II. *Verkehrsverhältnisse* = II. *Traffic conditions.*

Mutterbahnhof = Mother station.
Tochterbahnhof = Daughter station.
Bahnhof mit Güterabfertigung = Station despatching goods.
Haltepunkt nur für Personenverkehr = Train stopping place for passenger traffic only.

was taken at random and refers to the Igel-Bitburg section in the Trier Division of the Reichsbahn. The conversion took place in 1928. This section is 41 km. (25.5 miles) long and comprises, exclusive of the terminus, twelve service points with two train-control stations — Igel for the section up to but not including, Irrel, and Irrel for the section as far as but exclusive of Bitburg. The crossover points are very far apart and, therefore, unfavourable to simplified working. The daily service consists of ten passenger trains with accommodation for carrying goods, and two freight trains. The former are used by 30 to 150 passengers. In 1927 the business at the unattended stations averaged per day 43 tickets sold, 10.1 way-bills completed and 1.1 wagon loads handled. The simplified operation proceeds without difficulty. The timetable is just as good as previously. Table 3 gives particulars of the saving in staff and expenses.

The conversion of three similar routes in the Trier Division having an aggregate length of 116 km. (72 miles) has resulted in a saving of 15 employees and 2 707 working days, or a total of approximately 24 employees. On the average the expenditure in wages has declined at each of the stations that are now unattended, from 5 600 to 1 310 Rm., i. e. by about one fifth; the total saving on the three routes amounts to 83 000 Rm. per annum.

It is very difficult to determine precisely the magnitude of the saving that will result from the measures of operating simplification that are now being introduced on all routes of the Reichsbahn which lend themselves to the change, for the reason that in many places economies have already been introduced over a period of some years. But it is certain that the new methods of dealing with the question of the economic organisation of secondary lines will effect a reduction in expenditure of several millions of marks annually.

The economic working of trains that are not much used, although they operate on busy routes, calls for the application of the same fundamental ideas that have been employed on secondary lines. In particular the comparison which has been made between motor-coach stock and light steam trains holds good for main lines without any modification.

The position is somewhat different when goods trains are considered. Small freight trains on busy routes are normally required for carrying out special local duties, as for example, connecting up, transfer between neighbouring stations, bye-passing large stations in short-distance traffic, etc. These special cases are neither numerous nor of great importance from the economical side since there is not much scope for further saving, now that the train staff has been reduced to two, following the introduction of the continuous brake. It is not proposed to consider these cases further. But in addition to this class of work, small goods trains form a class by themselves as part of the detailed classification of freight in working goods traffic. Thus the relegation of express goods to special trains or the separation of parcels traffic from wagon-loaded traffic may require the systematic running of light-goods trains on main lines carrying a great deal of traffic. The object in view may be to improve traffic operating conditions, and in some cases they may be desirable for economic reasons.

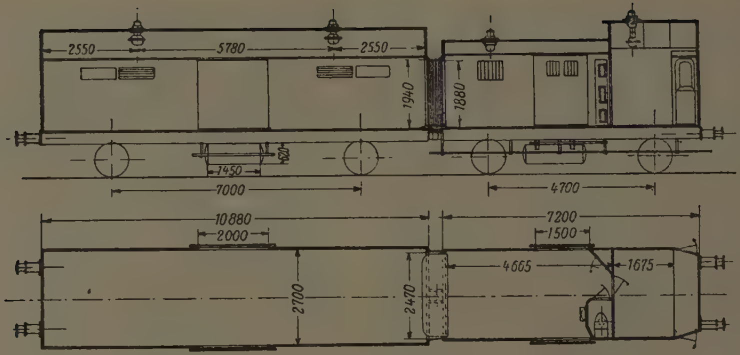
The Reichsbahn has recently found itself obliged, owing largely to the intensified competition of road transport, to make a whole series of new traffic arrangements for conveying parcels; it has departed from the principle of making full use of locomotives on heavy trains even on very busy main line routes, and has gone over to quite light parcels trains, known by the abbreviation «Leig» trains.

This type of train takes over from the existing short-distance and parcels trains the mixed parcels consignments, not including complete wagon loads that are made up; hence it takes the place of the « regular-service » wagon. The practice which had always been followed of forwarding sundry parcels in these wagons on heavy trains was extremely complicated. The « regular-service » wagon collected the goods for a particular destination from point to point or distributed them from the larger centres to the smaller stations. It was usual to find such wagons for the most divergent directions in one train. It followed that at every station where there was a busy traffic a whole group of wagons had to be loaded and unloaded. As the wagons from which the goods had to be set down or taken up were often widely distributed throughout the train, complicated shunting movements could not be avoided. Long delays resulted, the average speed became very low and the expenditure very high.

The method of working is quite different when a « Leig » train is used.

This light goods train consists of an ordinary locomotive and generally two wagons only, forming a permanent unit for handling the conveyance of separate parcels. The wagons are so arranged (figs. 13 and 14) that transfer of goods between them can be carried out during the journey; they have doors in the ends and flexible gangways. The wagons should be of large capacity, with good artificial lighting, heating, provision for sorting and filing way-bills, writing arrangements, lavatory, etc. Experience has shewn that a good combination consists of a luggage van and a large capacity freight wagon. In exceptional cases another covered wagon is added. Instead of distributing the packages over a large number of « regular-service » wagons, with these trains they are loaded into a roomy space in connected vehicles. The complicated and troublesome shunting is done away with. Loading and unloading are facilitated and carried out as quickly as possible by an excellent system of working aided by every suitable technical appliance. The shipment is prepared before arrival of the train, the separate packages being placed on lifting trolleys, trucks and containers in the sheds (fig. 15); similar arrangements for unloading are carried out on the train during the journey (fig. 16). Thus the « Leig » train is not only a self-contained power-propelled unit on rails, but also a travelling goods shed. The resulting simplification and speeding up of the handling is such that the running of « regular-service » wagons to serve branch lines can be dispensed with. No difficulties are experienced in the collection or delivery of large quantities of packages at junctions. It is recognised that the forwarding of goods by « Leig » service instead of by « regular-service » wagon necessitates far-reaching modifications of the « regular-service » wagon classifications; this is, in fact, generally an indispensable preliminary to the introduction of the « Leig » system. It is found expedient to load both slow and express goods on to these trains. The exclusion of express goods from « Leig » trains would prevent the fullest use being made of them, and would lead to the anomaly of express goods taking longer for transport than ordinary freight goods. A decision on this point must take into account the traffic conditions and tariffs pertaining to the case in question.

The « Leig » runs as a made-up unit directly to loading stages, sheds, ramps,



Two wagons close coupled for express piece goods traffic.
Fig. 13. — Light goods-train. Arrangement of wagons.

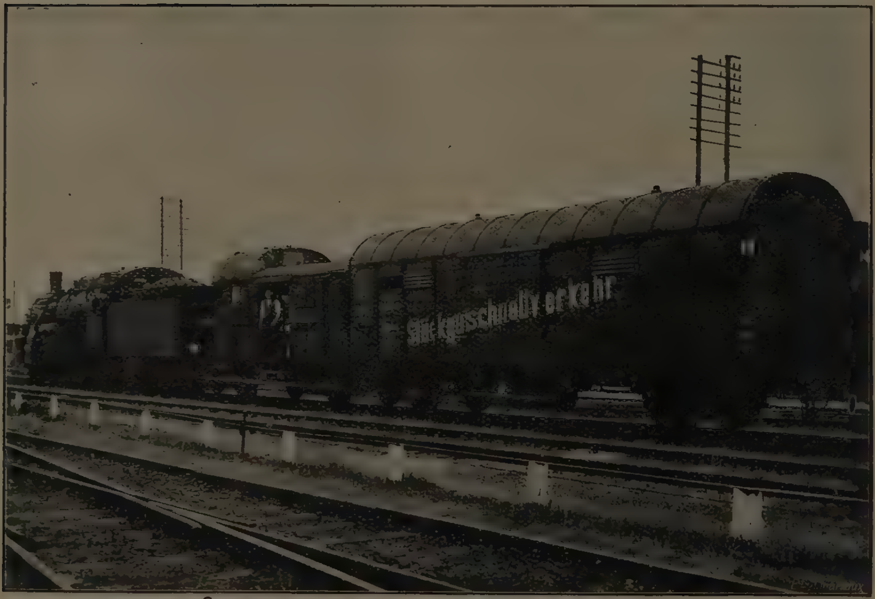


Fig. 14. — Light goods train. — General view.

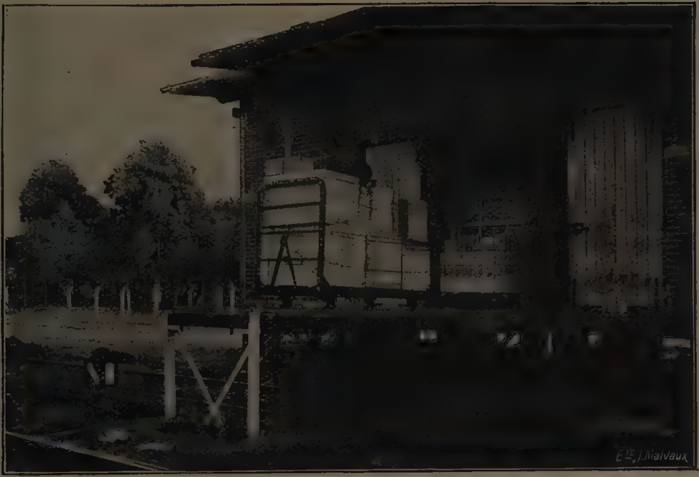


Fig. 15. — Goods made ready for loading.

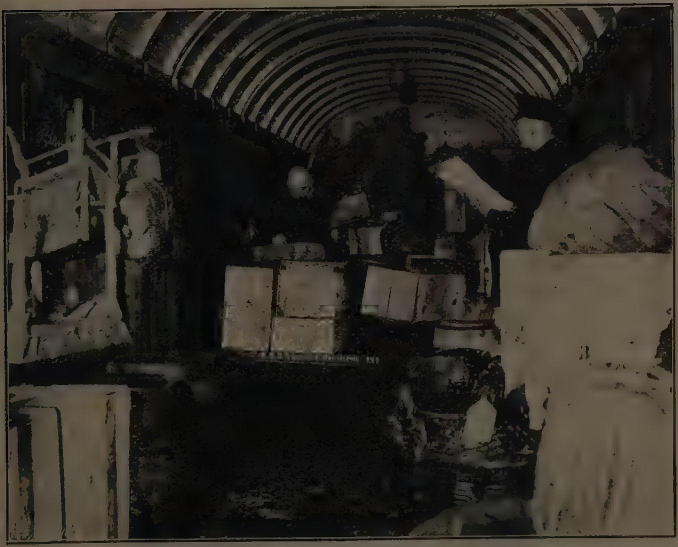


Fig. 16. — Working on a « Leig » train.

etc., for delivering and taking up packages. In those cases where the layout of the track or the signalling and safety arrangements do not permit the train to run right in, use is made of light bridges which are placed across the intervening rails. When necessary and the existing arrangements render it comparatively simple, a new siding is laid down. It is of the utmost importance that the stopping period should be reduced to a minimum by adopting the simplest system of working.

The maximum speed of the « Leig » is high and may be 70 km. (43.5 miles) per hour or more. Further, the small weight of the train results in a high average running speed which in conjunction with the short stops enables a journey speed to be attained which is from twice to four times the 10 km. (6.2 miles) per hour of a short-distance goods train.

It is not permissible, without the sanction of the Management, for wagons other than those belonging to the permanent make-up to be attached to a « Leig » train. Such sanction is only given in exceptional cases when it is definitely established that the journey speed will not thereby be reduced to a greater extent than is permissible, nor its traffic capacity be adversely affected.

In such cases as the proper working of the « Leig » does not suffer thereby, arrangements are made for the scheduled coupling of a « Leig » train to another train with a view to saving locomotive-mileage and staff. It is necessary above all to avoid interfering with the special purpose of a « Leig » train and converting it into a slow local goods train, either by adding wagons or connecting it to another train.

The economy resulting from the «Leig» train system depends upon its mobility and the saving of « regular-service » wagons which it effects.

The cost of running this class of train is recouped by the saving in train mileage which results from the elimination of other goods trains or the reduction of the aggregate train-hours worked on the route; the latter saving comprises time worked by locomotives, staff and wagons, or in carrying out work at depots, etc. In arriving at figures for train mileage it is not possible to take average values as a basis, since obviously a «Leig» train-mile is quite different to that of a full train load running at a lower speed. The great train mileage of the « Leig » can be justified economically by reason of the practical savings which result; the most important of these are due to the reduction in wagon-hours brought about by the speeding up of the local trains when they no longer have to deal with the parcels traffic, and by the elimination of the « regular service » wagon traffic. Thus, the economic justification for the employment of the « Leig » train is the two-fold advantage which it confers on the drawing up of the running schedule; it affords an extraordinarily good means of transport and at the same time relaieves other trains and enables them to be speeded up to a considerable extent.

On the other hand, the « Leig » system has proved unsuccessful from the economic, operating and traffic points of view, when full use has not been made of the possibilities of accelerating other freight trains and economising in « regular-service » wagon-hours.

The extent to which it is justifiable to arrange for running « Leig » trains in cases where their cost is not counterbalanced by other savings, depends upon the value attached to the improvements effected in the forwarding of « Leig » goods on the one hand, and on the other, of the goods carried by freight trains which are speeded up as a direct consequence of running the « Leig » trains. In appraising the financial value of these factors by far the most important consideration that has to be taken into account is that of road transport competition. The additional expenses entailed by a « Leig » train are justified when it enables the railway either to regain or prevent the loss of so much goods traffic that the increased or retained receipts cover that expenditure.

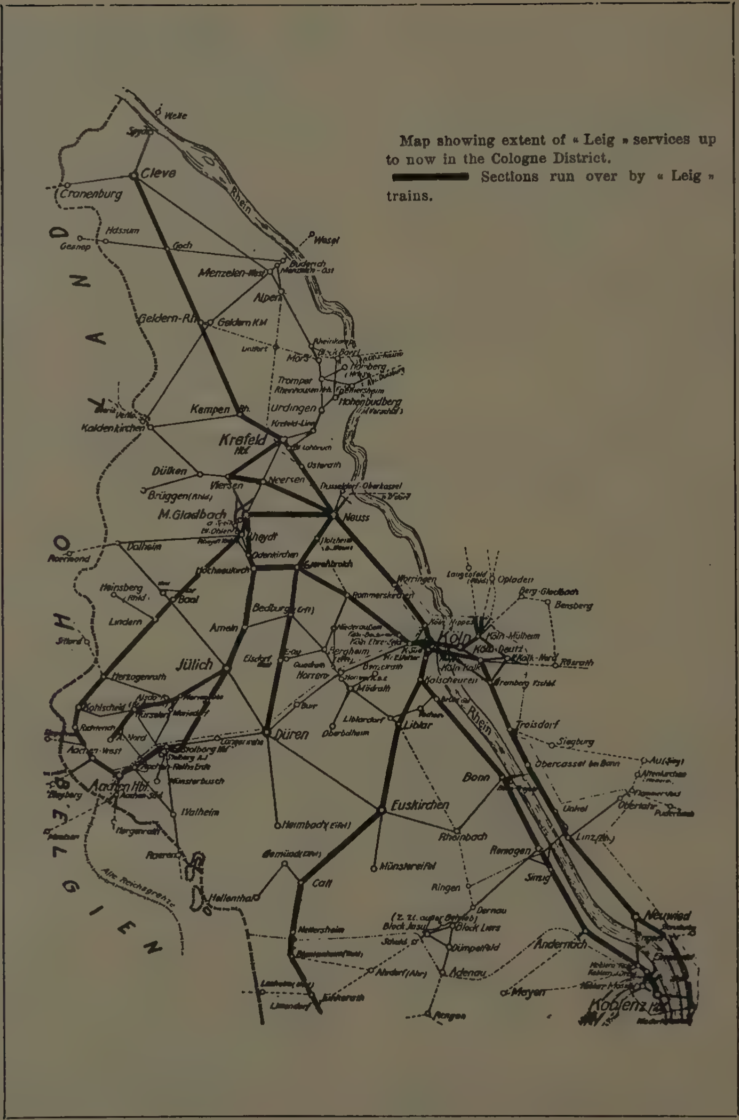
Any investigation of the economic question should, therefore, take into account not only the costs and savings in the operating and handling departments, but also the manner in which the traffic receipts are affected.

The question naturally arises as to why locomotives of normal type should be used for hauling such light trains and whether the use of such powerful haulage units for this purpose is economically sound.

The preliminary work carried out in relation to the « Leig » trains showed that for the purpose in question either a small steam train or a very heavy motor-coach with one trailer might be used. With the existing designs of motor-coach this type of vehicle is only as good as, or superior to, a steam train from an economic point of view, when it is very fully utilised. The cost of the power unit and of the power for a motor coach are unusually great for the high speeds — up to 75 km. (46.6 miles) per hour — and the loads of up to 20 tons, which are necessary in operating « Leig » trains. Hence, the Reichsbahn did not deem it advisable to incur considerable capital expenditure for their first experiments, particularly as a successful issue was by no means certain. Recourse was, therefore, had to the existing locomotives as substitutes for the motor vehicles which were not available. Later experience has proved this choice to be very satisfactory in every way, including the economy of the hauling unit. The use of a heavy locomotive does not necessarily mean a very high coal consumption, since the work to be performed is not heavy. Neither should it be overlooked that as a result of the progress made in locomotive design, fuel costs are no longer such a prominent factor, compared with other items of expenditure, as they were; the outlay on coal for the Reichsbahn is now only about 5 % of the total working expenses. Of even greater importance is the fact that the « Leig » takes its place with other trains on the locomotive rota, so that the locomotives and their personnel are much more fully utilised than is generally possible with motor-coaches.

The most economical arrangement for providing the locomotives for « Leig » trains, if the speed is not fixed at a figure that is too high, is that which permits both passenger and freight locomotives to be employed.

The financial results of the « Leig » train system are so favourable that the Reichsbahn is pushing forward their further development very energetically. As an example of what has been accomplished, figure 17 shows the « Leig » connections in the Cologne Division on practically all the important routes. The « Leig » trains in this district have an aggregate train-mileage per working day of 1 877 train-km. (1 166 train-miles) in 81 hours. The train staff work a total of 229 hours per day. The savings effect-



Map showing extent of « Leig » services up to now in the Cologne District.

▬ Sections run over by « Leig » trains.

Fig. 17. — The « Leig » services in the Cologne District.

Cologne Reichsbahn Division. **Köln-M. Gladbach.**

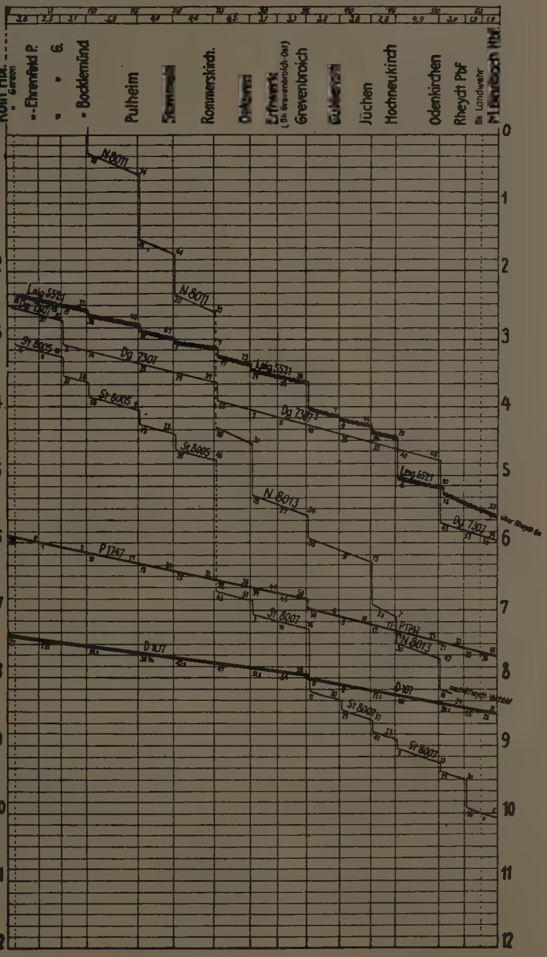


Fig. 18. — « Leig » time-tables.

ed in respect of other trains amount to 1 030 train-km. (640 train-miles), 113 train-hours, and 377 man-hours of train staff.

The high commercial speed of a « Leig » in comparison with a local goods train can be seen from figure 18. The « Leig » 5 521 has taken the place of the 8 005/8 007 indicated. Longer experience will show whether the «Leig» is destined to supersede entirely the « regular-service » wagon. Even at the present time the saving that has been effected in the latter class of wagons is very considerable. In the Cologne district only, after deducting the wagons used in the « Leig » trains, there has been a reduction in the number of such wagons required of 214 per day corresponding to 5 196 wagon-hours.

Although the Reichsbahn has had favourable results with small steam trains, this experience has by no means led them to decide against the use of motor-cars. In order to obtain further information on the question, they have put into service experimentally three Diesel motor-cars operated on parcels traffic (fig. 19).

The following figures give details of the weight, dimensions, motor output, etc. :

Length over buffers	21.04 m.	(69 ft. 3/8 in.)
Length of loading space	14.60/14.82 m.	(48 ft.—48 ft. 8 in.)
Width of loading space	2.79 m.	(9 ft. 2 in.)
Height of loading space	2.40/3.00 m.	(7 ft. 10 ½ in. — 9 ft. 10 in.)
Wheel base	16.92 m.	(55 ft. 6 in.)
Wheel base of bogie	3.50 m.	(11 ft. 6 in.)
Centres of king pins	13.30 m.	(43 ft. 8 in.)
Tare	39 t.	(38.4 Engl. tons)
Carrying capacity	20 t.	(19.7 Engl. tons)
Useful floor area	40.7 m²	(438 sq. feet)
Useful cubic capacity	93.6 m³	(122.3 cubic yards)
Horse power output of Diesel engine	150	
Maximum speed	75 km.	(46.6 miles)
Total trailer weight at maximum speed	30 t.	(29.5 Engl. tons)

The practical operation for comparative purposes of small steam trains and motor wagons for working goods traffic promises to yield a great deal of information on the subject of haulage economics.

B. — The use of special tractors for shunting in smaller yards and for certain work in large yards.

As on other large railway systems shunting operations at stations on the Reichsbahn which do not have very much goods traffic, and where it would not pay to have special shunting engines, are generally performed by the locomotive working the train on which wagons have to be taken off or coupled up. In suitable cases a special « travelling » shunting locomotive is sent to the stations requiring it for as many hours as it is needed. Both these arrangements are very expensive. The train locomotives are unnecessarily powerful for this work, so

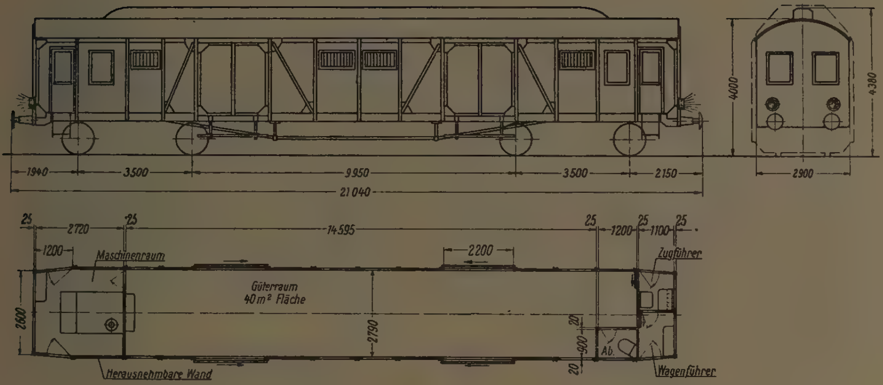


Fig. 19. — 150-H. P. Diesel motor wagon for goods traffic.

Explanation of German terms: Ab. = W. C. — Güterraum, etc. = Goods compartment, 430 sq. feet in surface. — Herausnehmbare Wand = Removable partition. — Maschinenraum = Engine compartment. — Wagenführer = Driver. — Zugführer = Train conductor.

that their use means that a disproportionate amount of capital is employed. Moreover, the resulting increase in the stopping time of the train through using its engine for shunting adversely affects not only the circulation of the engine, but also the utilisation of the wagons.

The interest, depreciation, and maintenance charges for a standing goods wagon on the Reichsbahn, amount on the average to 0.10 Reichsmark per hour. Thus, for a full train load of 60 wagons delays aggregating one hour entail an expenditure in respect of this item alone of 6.00 Reichsmarks. Taking the whole of the Reichsbahn railway system and assuming that improved methods of shunting result in a 50 % reduction in the long stopping times of loaded local goods trains, a permanent saving of approximately 7 000 wagons could be effected. Reference to the extraordinarily unfavourable influence exerted on traffic operation by shunting delays is only made in passing.

The use of a « travelling » locomotive for shunting certainly diminishes the time during which wagons are standing, but the movement of the light engine from station to station absorbs most of the resulting gain or even gives a loss as the net result.

In order to relieve the train locomotive, the Reichsbahn uses capstans, and in isolated instances horses, for minor shunting operations at some small stations. But the usefulness and capacity of these auxiliaries is so limited that they cannot effect a general improvement in shunting methods.

A step which seems likely to prove successful both technically and economically in overcoming the drawbacks of shunting with either the train locomotive or a « travelling » locomotive is the allocation to the stations in question of powerful motor tractors.

These confer on the stations the necessary degree of independence and freedom to carry out any movements required by the local operating and wagon services. It is no longer necessary for loading and coupling to be carried out in conjunction with the time-table for the local goods trains at times which are often quite unsuited to the local circumstances; the handling of goods can to a great extent be adapted to the convenience of the customers. The shunting duties are carried out by the local staff who can be relied upon to carry out the work more accurately than the continually changing staff of the trains.

The tractor is worked by one man only, and the method of operation is so simple that specially skilled staff is unnecessary; the required training can be imparted in a few days and is not more than that needed by a motor-cyclist. The driver can be used to assist in other work, which is a great advantage from the point of view of economy.

The improvement of the time-table which is such an urgent necessity can be attained with the greater completeness, the more stations on a given route are equipped simultaneously with these motor locomotives. The capacity of the line is improved since the speed of the local goods trains does not then differ so much from that of the other trains, and fewer passings are necessary; further, the line is relieved of the « travelling » locomotives running light from station to station.

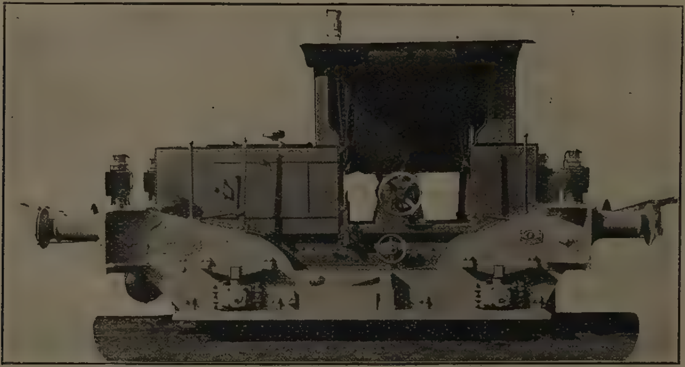


Fig. 20. — Schwartzkopff motor tractor. — General view.

The new system permits the number of trainmen on many local goods trains to be reduced, since it is no longer necessary to provide them with assistant guards to help with the duties en route. Employees allotted to wayside stations in consequence of their equipment with a tractor assist with loading and unloading.

It is realised that the question of whether it is economically sound to instal a motor tractor, requires consideration of all the duties at the individual stations and of the time-table of the whole of the line. It is not sufficient simply to compare the costs of haulage.

The demand for small motor locomotives for industrial purposes during the last few years has led to considerable progress in their technical development. Therefore, they are obtainable in many different designs suitable for light duties in railway service. Figures 20 and 21 show, as an example, the Schwartzkopff design, which was first tried for railway work on the Netherlands State Railways; figures 22 and 23 show the Windhoff tractor; figure 24 that of the Deutzer Motorenfabrik; a further type is that manufactured by the A. E. G. (Allgemeine Elektrizitäts-Gezellschaft).

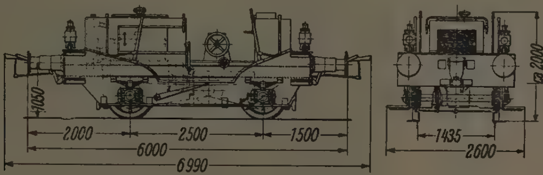


Fig. 21. — Schwarlzkopff motor tractor. — Details.

All the above-mentioned types are sufficiently heavy to provide adequate adhesion between wheels and rails correspondingly to the tractive force which they exert. In other designs, as that of Breuer (figs. 25 and 26) the idea has been utilised of using a lighter vehicle and supplying the additional friction-weight required when hauling heavy groups of wagons by securing the tractor underneath the wagon in such a way that part of the wagon weight is taken by the tractor. If a few wagons only are to be hauled, the tractor's own weight is sufficient without the additional loading. In spite of its lower price, this design suffers from the disadvantage that on the average a longer time is required for coupling and uncoupling the tractor and its load. The shunting operations are thus made more troublesome. Therefore, it appears more satisfactiry to increase the adhesive weight, when necessary, by loading the tractor with weights in the form of, say, concrete blocks, rather than to obtain the increased weight from a wagon that is being hauled.

The Reichsbahn has not at present considered carrying out tests with vehicles of the lighter type.

The general arrangement of the tractor must be such that the driver always has a good view of the whole train, even on curves; it must not be obligatory for him to remain in the centre of the vehicle while shunting, in fact it should be possible for him to look out easily from one side or the other while he is driving. It should also be possible for him to travel forwards or backwards with equal safety. The driver's position is better if kept low enough to facilitate getting on and off quickly and easily; provision should be made for sheltering him from rain and snow. Coupling-up should take place automatically when the tractor is run up to a wagon, and release of the coupling should be effected by the driver operating a lever from his driving position. With the features described above, it is possible for shunting operations under straightforward conditions to be carried out by one man.

The driving power should be switched off automatically in the event of the driver becoming incapacitated or thrown off the tractor by violent shunting.

The working speed of tractors need not

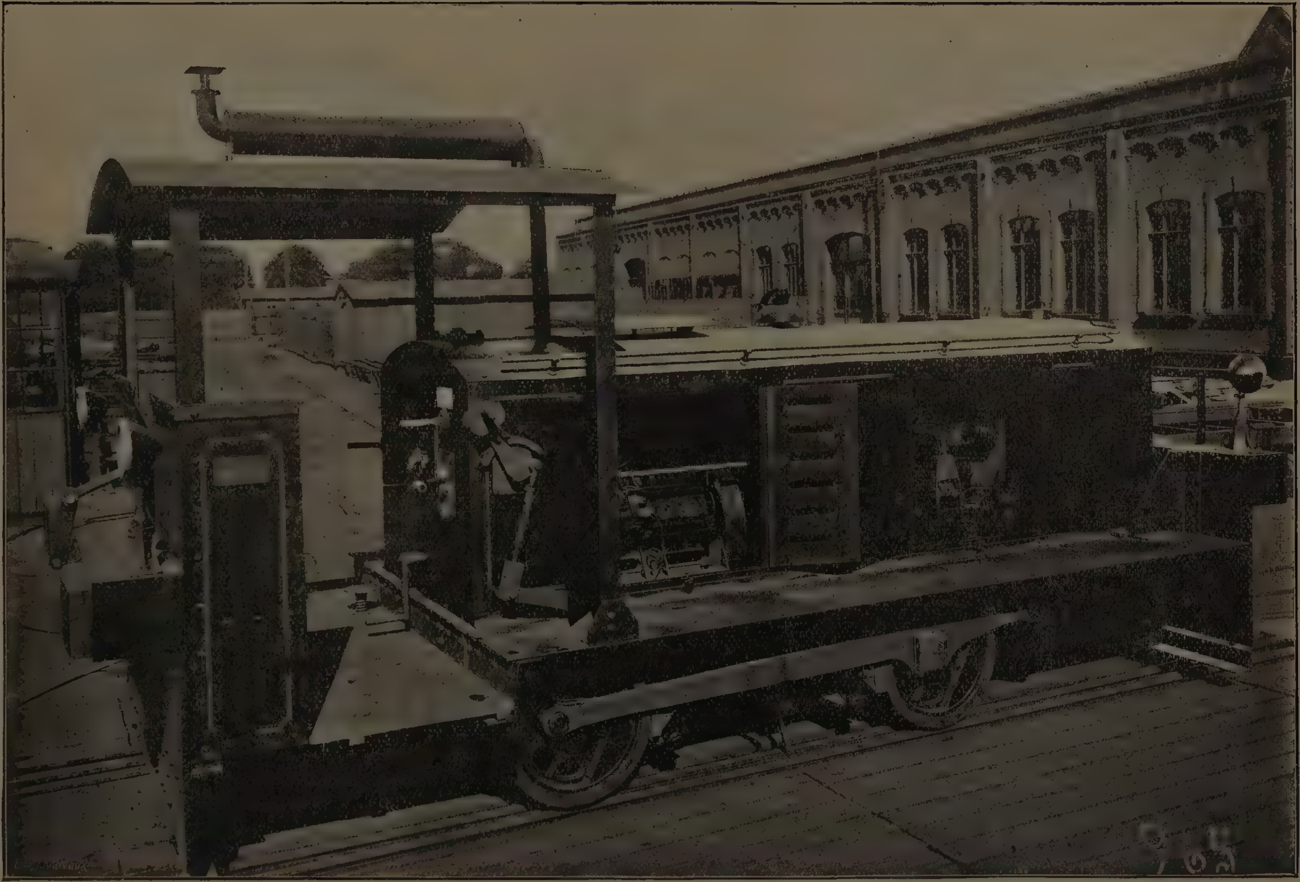


Fig. 22. — Windhoff motor tractor.

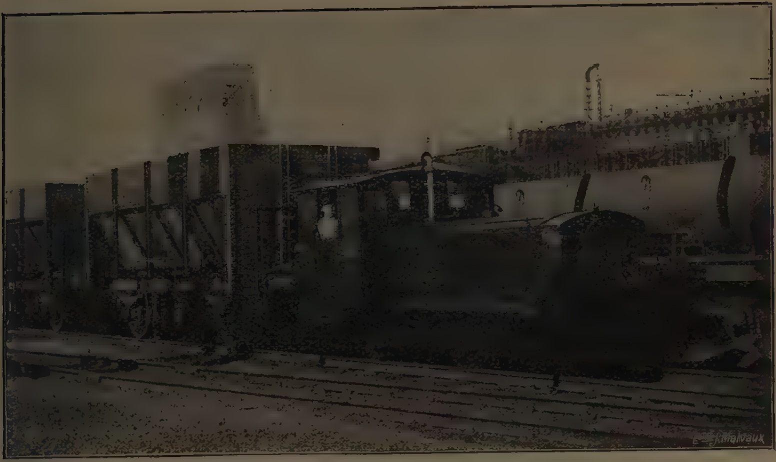
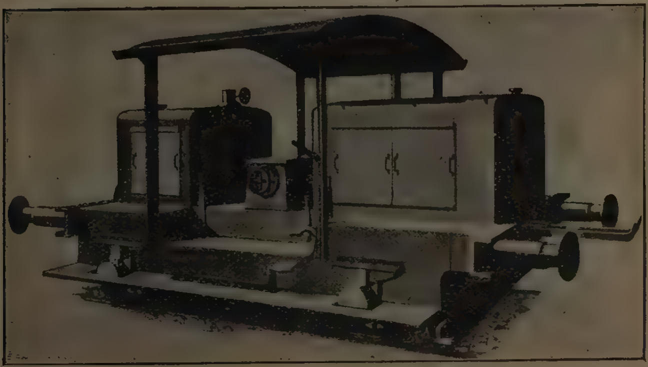


Fig. 23. — Windhoff motor tractor in action.



Fig, 24. — Deutz motor tractor.

be great; 4 to 8 km. (2.5 to 5 miles) per hour is sufficient. But it should be possible for the tractor to run light to another point at a higher speed, say, 20 to 30 km. (12.4 to 18.6 miles) per hour. The hauling capacity should be sufficient to start and haul slowly a train weighing up to 300 t. (295.2 Engl. tons) on the level. Experience shows that a tractive effort of about 2 000 kg. (4 400 lb.) is sufficient at a speed of 4 km. (2.5 miles) per hour.

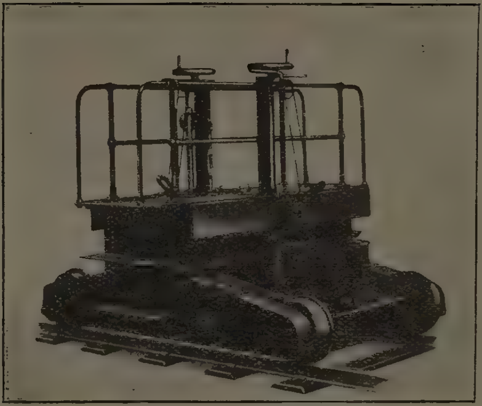


Fig. 25. — Breuer motor tractor.

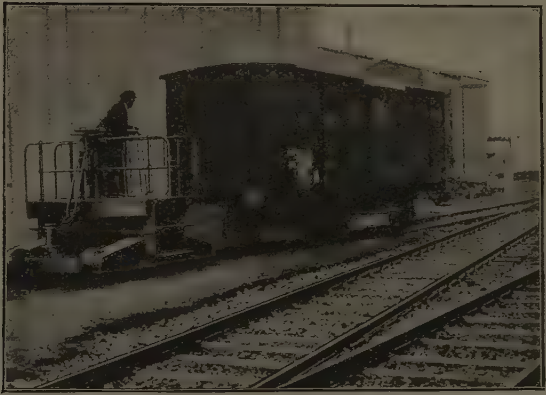


Fig. 26. — Breuer motor tractor before coupling up.

Most of the ordinary types are driven by petrol engine, Diesel engine, or electrically by accumulators.

In comparison with other internal combustion engines, the Diesel engine is not only superior in point of low fuel consumption, but it has also the important advantage that the heavy oil which it uses is less inflammable than petrol or benzol, and consequently it is not necessary to provide specially protected storage accommodation. In addition, the Diesel engine is less susceptible to freezing, which simplifies and cheapens the construction of the tractor shed.

The cost of an electric tractor is somewhat greater. Then again, additional expenditure is entailed when only alternating current is available in connection with the provision of the necessary rectifying plant. Nevertheless, the higher capital expenditure is offset by certain operating advantages which happen to be particularly important for the class of work under consideration. Operation is simpler than with any other type. The accumulators can be charged simply by switching them on the supply mains and after charging is completed the circuit is opened automatically. Ample time is available for the charging since shunting operations are only conducted intermittently. The starting effort is very great and the weight of the heavy accumula-

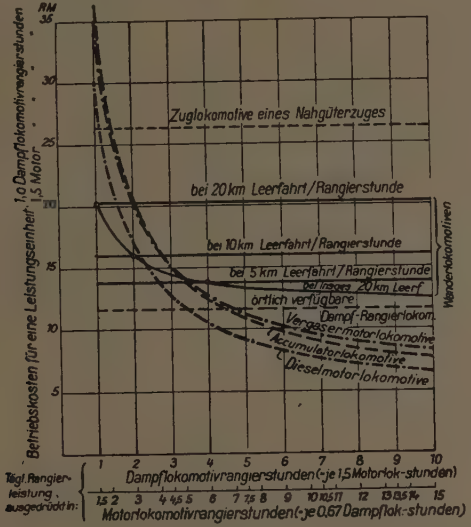


Fig. 27. — Economic results of station shunting with steam or motor locomotives.

Explanation of German terms: Akkumulatorlokomotive = Accumulator locomotive. — Bei... km. Leerfahrt/Rangierstunde = For... km. of light running per hour of shunting. — Bei insges. 20 km. Leerf. = For total of 20 km. light running. — Dieselmotorlokomotive = Diesel motor locomotive. — Oertlich verfügbare Rangierlokomotive = Steam shunting locomotive vacant on the spot. — Vergasermotorlokomotive = Explosion motor locomotive. — Zuglokomotive eines Nahgüterzuges = Locomotive of a short-distance goods train.

Ordinate (left) : Operating costs per working unit : 1 hour shunting with steam locomotive; 1.5 hours shunting with motor locomotive.

Abscissa: Daily shunting work expressed in : hours of shunting with steam locomotive (equal each to 1 1/2 hours shunting with motor locomotive); hours of shunting with motor locomotive (equal each to 0.67 h. of shunting with steam locomotive).

TABLE 4. — **Operating costs of sma**

1			2		3			4		
1. Type of motor locomotive			Windhoff.		Schwartzkopff.					
2. Motors, number and type			1 Petrol.		1 Diesel.			1 Petrol.		
3. Motors, horse power			40		40			40		
4. Source of power			Petrol.		Oil.			Petrol.		
5. Costs per kgr. of fuel or per kw.-h. of current. Rm.			0.32		0 12			0.32		
6. Weight of locomotive . . . tons.			13		11			9		
7. Capital cost (approximate) . . . Rm.			20 000		19 000			16 200		
8. Annual charges for interest, depreciation, and maintenance, 25 °/₀ of capital cost			5 000		4 750			4 050		
9. Speeds . . . Km. per hour			4	8	4	8	30	4	8	
10. Tractive effort at drawbar hook at the above speeds . . . kgr.			2 100	1 050	1 850	850	∽ 110	1 850	850	∽
11. Maximum weight of wagons hauled . . . tons.			350	175	310	140	18	310	140	
12. Fuel or current consumption	Kgr. (kw.-h) per E. H. P.-hour.		0.30 kgr.		0.25 kgr.			0.30 kgr.		
	Rm. per E. H. P.		0.096		0.03			0.096		
13. Lubricating oil consumed	Rm. per E. H. P. hour		0.006		0.007			0.005		
	Kgr. per E.H.P. hour		0.003		0.004			0.003		
14. Operating costs per hour at average output of 16 H. P. Rm. per hour			1.58		0.54			1.58		
15. Cost per hour of operator and additional shunter together . . . Rm. per hour.			2.00		2.00			2.00		
16. *Interest, amortisation and maintenance charges per hour*, based on 255 useful days per year and a daily working time of :	1 hour	Rm. per hour.	19.60		18 60			15.90		
	2 hours	—	9.80		9.30			7.95		
	3 —	—	6.53		6 20			5.30		
	4 —	—	4.90		4 65			3.97		
	5 —	—	3.92		3.72			3.18		
	6 —	—	3.26		3.10			2.65		
	8 —	—	2.45		2.33			1.98		
	10 —	—	1.96		1.86			1.59		
	12 —	—	1.63		1.55			1.33		
	15 —	—	1.31		1.24			1.06		
17. *Total operating costs per hour*, based on a daily working time of :	1 hour	Rm. per hour.	23.18		21.14			19.48		
	2 hours	—	13.38		11.84			11 53		
	3 —	—	10.11		8.74			8.88		
	4 —	—	8.48		7.19			7.55		
	5 —	—	7.50		6.26			6.76		
	6 —	—	6.84		5.64			6.23		
	8 —	—	6.03		4.87			5.56		
	10 —	—	5.54		4.40			5.17		
	12 —	—	5.21		4.09			4.91		
	15 —	—	4 89		3.87			4.64		

Remarks : *Row 15.* — It is assumed that 2 men are allocated to the locomotive. One drives it and the ot who couples up the wagons in addition to driving.

Column 8, rows 6 and 10. — The adhesive weight can be increased by drawing the motor vehicle up tractive effort without this additional loading ; the lower figures with the additional loading.

tor locomotives of various types.

5				6				7				8		
Deutz.				Ilsenburg.				A. E. G.				Breuer.		
1 Diesel.				1 Diesel.				2 Electric.				1 Petrol.		
40/44				36/40				2 × 21 = 42				40		
Oil.				Oil.				Accumulators.				Petrol.		
0.12				0.12				0.08				0.32		
12				15				10				3.8 t.; see remark.		
18 000				17 400				21 360 (of which 3 000 for rectifier).				12 000		
4 500				4 350				5 390				3 000		
4	8	15	30	4	8	15	30	5	13	20	30	3 3	6.3	15.3
920	920	∽ 400	∽ 120	1 450	1 000	425	125	1 800	500	200	∽ 130	$\frac{950}{2\,100}$	$\frac{500}{1\,100}$	$\frac{200}{450}$
320	155	65	20	240	170	70	20	300	85	33	22	350	180	75
0.27 kgr. 0.032				0.30 kgr. 0.036				0 735 kw-h. 0.059				0.30 kgr. 0 096		
about 0.007 0.004				0 007 0.004				0.007 0.004				0.006 0.003		
0.58				0.64				1.00				1.58		
2.00				2.00				2.00				2.00		
17 60				17.00				21.20				11.76		
8 80				8.50				10.60				5.88		
5.87				5.67				7.07				3.92		
4.40				4.25				5.30				2.94		
3.52				3 40				4.24				2.35		
2 94				2.83				3.54				1.96		
2 20				2.13				2 65				1.47		
1.76				1.70				2.12				1.18		
1.47				1.42				1 77				0.98		
1.17				1.13				1.41				0.78		
20.18				19.64				24.20				15.34		
11.38				11.14				13 60				9.46		
8 45				8.31				10.07				7.50		
6.98				6 89				8.30				6.52		
6.10				6 04				7.24				5.93		
5.52				5 47				6.54				5.54		
4.78				4.77				5.65				5.05		
4 34				4 34				5 12				4.76		
4.05				4.06				4.77				4.56		
3.75				3.77				4.41				4.36		

orks as shunter. In practice it is sufficient for the light duties at small stations to be dealt with by *one* man

he wagon so that it takes part of the weight of the latter. In row 10, the upper figures are values of

Table 5.

Operating costs for shunting with steam locomotives.

1	2	3	4
1. Type of locomotive	with	without tender	without
2. Weight in working order (*with* tender in column 2)	105	36	54
3. Interest and amortisation (10 % of initial cost) Rm. per annum	13 400	4 370	6 720
4. Interest and amortisation for 3 060 *useful* hours per annum . . . . . Rm. per useful hour	4.30	1.45	2 20
5. Fuel and locomotive maintenance Rm. per shunting hour	4.30	2.65	3 05
6. Locomotive crew : driver and fireman Rm. per shunting hour	6.55	6.55	6.55
7. Total locomotive costs (lines 4 + 5 + 6) Rm. per shunting hour	15.15	10.65	11.80
8. Costs per locomotive-kilometre *running light* Rm. per km.	0.61	0.43	0.48
9. One conductor and two guards (short distance goods trains) . . . . Rm. per hour	8.30	—	—
10. One shunter . . . . Rm. per hour	1 00	1 00	1.00
11. Idle time of 28 wagons (average make-up of short-distance goods trains) . Rm. per hour	2.80	—	—
12. Total costs for shunting with train locomotive (Lines Nos. 7 + 9 + 11) . . Rm. per hour	26.25	—	—
13. Total costs for shunting with shunting locomotive *without* light running (lines 7 + 10) Rm. per hour	16.15	11.65	12.80
14. Total costs for shunting with shunting locomotive *with* light running as below :			
1 km. light running per shunting hour (Nos. 7 + 8 + 10) . . . . Rm. per hour	16.76	12.08	13.28
5 km. light running per shunting hour (Nos. 7 + 5 × No. 8 + No. 10) Rm. per hour	19.20	13 80	15.20
10 km. light running per shunting hour (Nos. 7 + 10 × No. 8 + No. 10) Rm. per hour	22.25	15.95	17.60
20 km. light running per shunting hour (Nos. 7 + 20 × No. 8 + No. 10) Rm. per hour	28 35	20.25	22.40

tors increases the adhesion between wheels and rails.

Final decision as to the utility of the various types can only be arrived at after the Reichsbahn has had a longer and more thorough experience of them under working conditions.

Table 4 gives a summary of the most important constructional and economic data both for the types that have been tested by the Reichsbahn and also for the Breuer tractor.

Table 5 gives the data relating to shunting with steam locomotives that is necessary for a comparison from the economic point of view.

In making a comparison between the figures in the preceding tables it is necessary to bear in mind that a steam shunting locomotive can do more work in a given time than a motor locomotive. The work done by a steam locomotive in one hour can only be done by a motor locomotive in 1½ hours. Therefore, figure 27 shows the cost of shunting with a steam locomotive for one hour and the cost of shunting with a motor locomotive for 1½ hours. From this it appears that the employment of a motor tractor becomes more economical than shunting with a steam locomotive if approximately 1½ hours standing time can be saved, or about 2 to 4 shunting hours of a « travelling » locomotive or a shunting locomotive that is available locally. The superiority of the motor locomotive increases very rapidly the more continuously it is utilised, since the cost per shunting hour diminishes quickly as the number of hours increases; the costs of a « travelling » locomotive on the other hand fall much more slowly, while those of a train locomotive do not in the nature of things diminish at all.

The high interest charges ruling in Germany affect the result to some extent; an average value of 7 % for the ensuing years has been assumed for the purpose of calculation. The general conclusion would not, however be altered appreciably if the rate of interest were lower.

Table 6 gives a summary of the results obtained in lengthy trials at three stations, and throws some light on the practical financial results obtained by installing motor locomotives.

Special mechanical appliances for use in place of shunting locomotives at large stations have up to the present been adopted by the Reichsbahn in only a few isolated cases. At Dresden-Friedrichstadt and Chemnitz-Hilbersdorf trains which are to be split up are coupled to a continuously running rope and hauled up to the starting point. Further information concerning this arrangement is given in the Report on « Methods to be used in marshalling yards to control the speed of wagons being shunted, and to ensure they travel on to the lines in the various groups of sidings » relating to question X for discussion by International Railway Congress Association meeting at Madrid in 1930. Other devices serve for pushing up wagons which have stopped short in the collecting roads of a shunting yard after running down from the hump.

Such arrangements are called upon to fulfil several duties simultaneously.

The most important is to increase the working capacity of the yard. In the absence of a special device of this description the wagons that have stopped short at intervals must be pushed up from time to time by a shunting locomotive travelling into each collecting road in turn. Generally speaking the wagons have to be pushed up from the direction from which they have come. This can only be done

Results of installing motor locomoti

Previously tender locomotives were u

—	Lüdinghausen Station.		
	Daily duty.	Costs for 300 working days	
		Unit rate.	Per annu Reichsma
A. *New expenditure* on installing Windhoff motor locomotive.	8 hours.	6.03 Rm. per motor-locomotive hour (col. 2, row 17 of table 4).	14 47
B. *Expenditure saved :*			
1. Stopping of train with shunting by train locomotive.	7 train-hours.	26.25 Rm. per hour (col. 2, row 22, table 5)	54 97
2. Shunting locomotive work in stations.	...	...	...
3. Light running of locomotives	...	...	...
4. Acceleration of wagons, insofar as not included in B 1 above.	20 wagons. 1.5 hours each.	0.10 Rm. per wagon-hour col. 1, row 19, table 5).	90
Total for B			55 87
C. Total annual saving (B-A)			41 40

Table 6.

3 stations in the Munster Division.

ccordance with table 5, column 2.

Lübbecke Station.			Twistringen Station.		
Daily duty.	Costs for 300 working days		Daily duty.	Costs for 300 working days	
	Unit rate.	Per annum, Reichsmarks		Unit rate.	Per annum Reichsmarks
7 hours.	6.38 Rm. per motor locomotive-hour (col. 2, row 17 of table 4).	13 400	7.5 hours.	6.23 Rm. per motor locomotive-hour (col. 2, row 17 of table 4).	13 880
1 train-hour.	26.25 Rm. per hour (col. 2, row 22 of table 5).	7 875	1 train-hour.	26.25 Rm. per hour (col. 2, row 22 of table 5).	7 875
4.5 shunting hours.	16.15 Rm. per hour (col. 2, row 23 of table 5).	21 785	4.2 shunting hours.	16.15 Rm. per hour (col. 2, row 23 of table 5).	20 350
...	...	...	2 × 26 km. light locomotive.	12.25 Rm. for 2 × 10 light km. (col. 2, row 20e of table 5).	9 555
20 wagons, 25 hours each.	0.10 Rm. per wagon hour (col. 1, row 19, table 5)	1 950	19 wagons, 0.75 hours each.	0.10 Rm. per wagon-hour (col. 1, row 19 of table 5).	430
		31 610			38 310
		18 210			22 235

by interrupting for the time being the running down of wagons, at any rate, into some of the roads. If on the other hand the wagons are closed up by an engine at the lower end of the marshalling sidings in the direction opposite that of shunting, the top part of the sorting sidings can only be cleared again by moving the large groups of wagons down again, so that a backward and forward movement ensues which is equally troublesome.

Usually the closing up is performed by the same locomotive that is used for pushing the train up the shunting hump; the use of a second locomotive for the purpose necessarily results in the first having idle periods during the interruptions to the working of the hump.

In a shunting yard that is working to full capacity some six to eight hours daily may be lost by this method of working, which is equivalent to a reduction in the output of the yard by from 1/4 to 1/3.

Special auxiliary closing-up equipments must be combined in such a way that the wagons are pushed up in the collecting roads without interrupting the running down from the hump; that is the essential point. Any disturbance or endangering of the closing up by the flow of wagons must absolutely be ruled out; only under this condition is the capacity of the yard really increased to a considerable extent. Even then it is not possible to obviate entirely some interruption to the working of the shunting locomotive, for occasions always arise when it is necessary for a locomotive to enter the marshalling lines in order to take out wagons which have been wrongly directed. Nevertheless, the installation of a closing-up system having the features outlined above reduces the time lost in running the wagons to a fraction of its former value. Completion of the outgoing trains is accelerated; the time-table and traffic operation are, therefore, improved.

The second function of a closing-up arrangement is to avoid damage to wagons and their loads through the buffering up of the moving wagons. Even at a low speed rebounding of the wagons is extremely harmful, because the kinetic energy has to be destroyed in the short distance which corresponds to the compression of the buffers. If a closing-up device is available, the wagons can be stopped before they collide without disadvantage; they are afterwards brought together at quite a low speed.

Thirdly, the closing-up device permits the very expensive steam locomotive to be replaced by apparatus that is substantially cheaper.

An arrangement of the type in question installed at Munich-East and constructed according to the proposals of Doctor Bäseler, takes the form of a rope winch clear of the tracks. The electric driving motor is of 12 H. P. and stands outside the rails. The rope runs in a narrow channel from one side of the yard to the other underneath the rails, and can be drawn out by the shunter, when required, through openings between the two rails provided with guide rollers (fig. 28). The end of the hauling rope is brought to the opening before being drawn out by an auxiliary rope operated by a separate small winch driven by a 2-H. P. motor. The two winches are under the control of a second shunter, who also assists with the coupling up, and are remote electrically-controlled from switches at the opening in the hauling rope channel. The hauling rope can be drawn out about 150 m. (492 feet), and this is ample to ensure that the upper end of the collecting road can be kept clear. The tractive force at a speed of 0.40 m. (1.31 feet) per second is 1 500 kgr. (3 300 lb.) The cost of installation amounts to 18 000 Reichsmarks for twenty roads. In operation this arrangement has proved reliable and very economical. It is proposed to facilitate the withdrawal of the hauling rope by providing a second auxiliary rope close up to the rail, to which the haulage rope can be connected, as required, and drawn out.

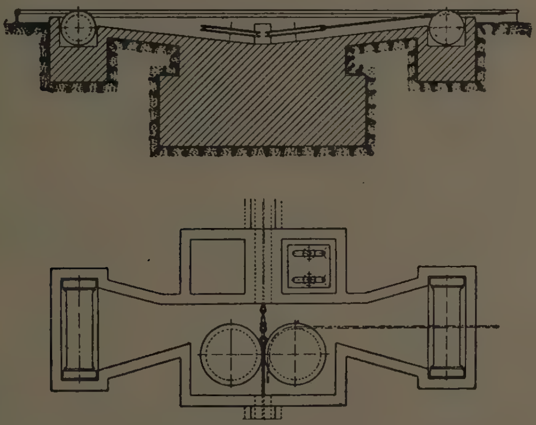


Fig. 28. — Guide pulley for rope winch at Munich East.

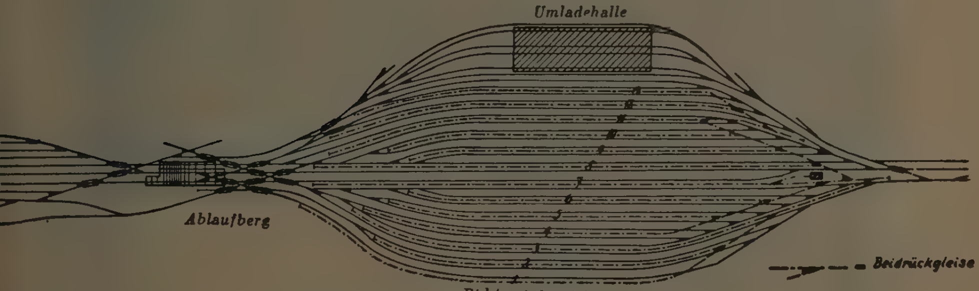


Fig. 29. — Auxiliary shunting equipment at Rothensee. — Track plan.

Explanation of German terms: Ablaufberg = Gravity hump. — Beidrückgleise = Tracks for closing up wagons. — Richtungsgruppe = Sorting sidings. — Umladehalle = Transhipping shed.

The Magdeburg-Rothensee shunting yard is provided with an auxiliary shunting equipment of a type proposed by the author; this consists of an accumulator tractor of large capacity.

The tractor runs on a narrow gauge line of 75 cm. (2 ft. 5 ½ in.) gauge, which is laid between each pair of marshalling roads (figs. 29 to 30). By guiding the tractor on rails the essential condition of safety is ensured and the tractor can work without danger among the moving wagons. The top of the narrow gauge rails is at the level of the underside of the main line rails, so that free passage between the latter is not in any way interfered with. Further, since no special construction of the surface between the rails is required, the drainage of the yard is not affected. At the lower end of the group of marshalling roads the tractor roads are connected by groups of points which cross the standard gauge lines. Any other connections have been omitted as undesirable, since they could not be used without interfering with the flow of wagons. The distance between the centres of the marshalling roads is 4.50 m. (14 ft. 9 in.), and accordingly the external shape of the vehicle (fig. 31) has to be designed to suit the narrow space that is available. The tractor was built by Messrs. Siemens-Schuckert; it is only 1.04 m. (3 ft. 5 in.) wide, its height above the crown of the rails is 1.15 m.

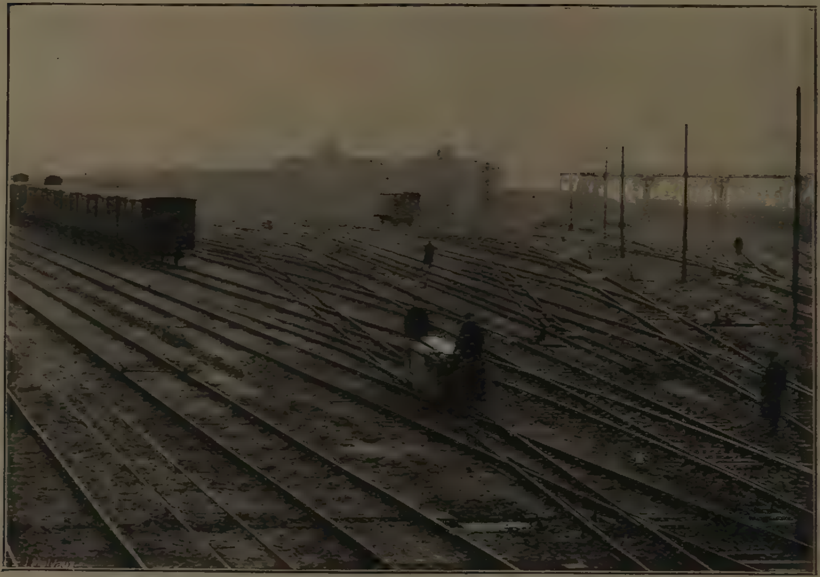


Fig. 30. — Auxiliary shunting equipment at Rothensee. — Track arrangement.

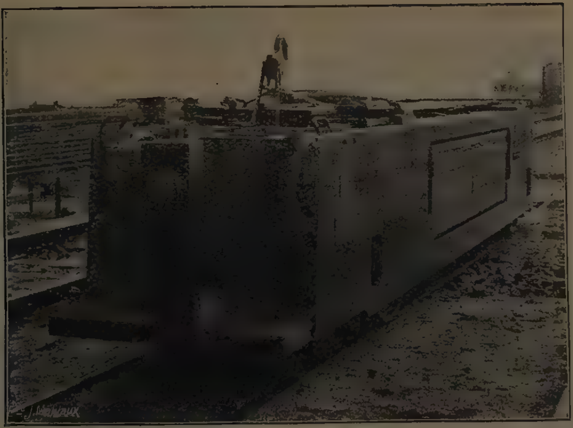


Fig. 31. — Tractor for Rothensee.

(3 ft. 7 11/16 in.), and its overall length 6.37 m. (20 ft. 10 3/4 in.). The wheel diameter is 750 mm. (2 ft. 5 1/2 in.), the wheel base 3.52 m. (11 ft. 6 9/16 in.), and the service weight 9.3 t. (9.15 Engl. tons). It is driven by two direct-current motors having a total rating of 18 H. P. (= 13.3 kw.). The maximum measured tractive effort is 2 355 kgr. (5 190 lb.); on a steady haul the corresponding figures are 671 kgr. (1 480 lb.) at a speed of 2.5 km. (1.55 miles) per hour, 511 kgr. (1 125 lb.) at 3 km. (1.86 miles) per hour and 219 kgr. (482 lb.) at 4.4 km. (2.73 miles) per hour. The tractive effort is sufficient to start a group of wagons weighing up to 200 tons; when a section has been set in motion and is brought slowly against standing wagons, the tractor is capable of proceeding with up to 500 tons. The maximum speed when running alone is 20 km. (12.4 miles) per hour.

This vehicle has a battery of 65 accumulator cells, giving a pressure of 130-

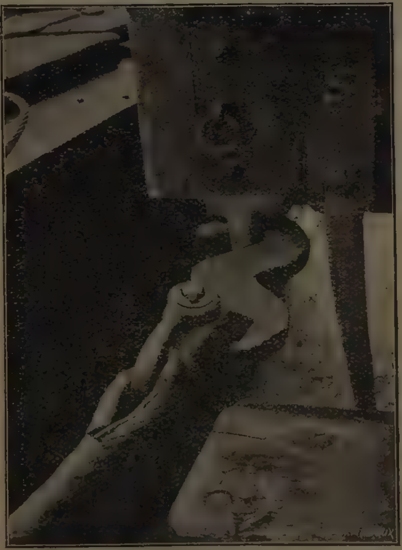


Fig. 32. — Draw hook of Rothensee tractor engaged in cable eye.

150 volts. Two batteries are used, one being on charge whilst the other is in service. The batteries are changed by means of a roller way. Power for charging is obtained from a small rectifying plant fed from the alternating-current lighting system.

The driving position is at one end, and at the other a low platform is arranged which can accommodate three other people.

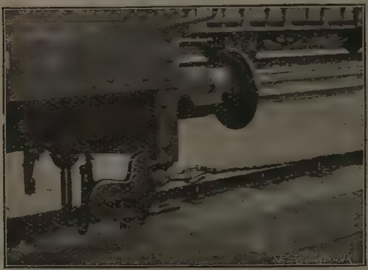


Fig. 33. — Daw hookr of Rothensee tractor on headstock.

For connecting the tractor to the wagons quite a short wire rope with a hook is used, and one such rope is fixed to the tractor by a spring on each side of the driving position. The hook is so shaped that it can be connected either to a cross beam of the wagon or to the shunting eye (figs. 32 and 33).

The driver couples the tractor to the wagons without leaving his post (fig. 34).

The cost of this installation was made up as follows :

	Reichsmarks
Tractor	12 750
Accumulators	11 445
Rectifying plant and wiring.	3 489
Shed	4 350
Track, points, crossings .	135 784
Total	167 818

The tractor systematically closes up the trucks so that each train is ready to proceed up to time. A second man travels with the driver for coupling up the train. This system has operated for two years day and night, in all weathers, including deep snow, without any trouble having been experienced.

The good speed of the tractor when running light and the fact that it runs on rails, enables it to be crossed over from one road to another at the lower end of the marshalling yard, without much loss of time, and this is done safely because it is effected beyond the region where the wagons are in motion. A pointsman supervises the crossing of the main tracks. The points of the narrow gauge track are set by the driver of the tractor. Communication between the tractor and the official in charge of the shunting is carried out by a horn and by telephone.

The railwaymen take very kindly to the equipment, owing no doubt to the extreme simplicity of the electrical operation and the arrangement of the rails, and as a result the shunting operations are carried out at a comfortable speed. Damage to wagons and consignments is a thing of the past, since the men, contrary to their former custom, now slow down the wagons in good time for them to come to a standstill before they reach the one in front; this eases the work of the tractor, as it usually has only a small group of wagons to set moving.

In spite of the not inconsiderable initial outlay, the economic results are just as satisfactory as the capacity of the tractor for carrying out the required duties.

The introduction of the tractor equipment into the shunting yard resulted in an annual saving of 793 locomotive

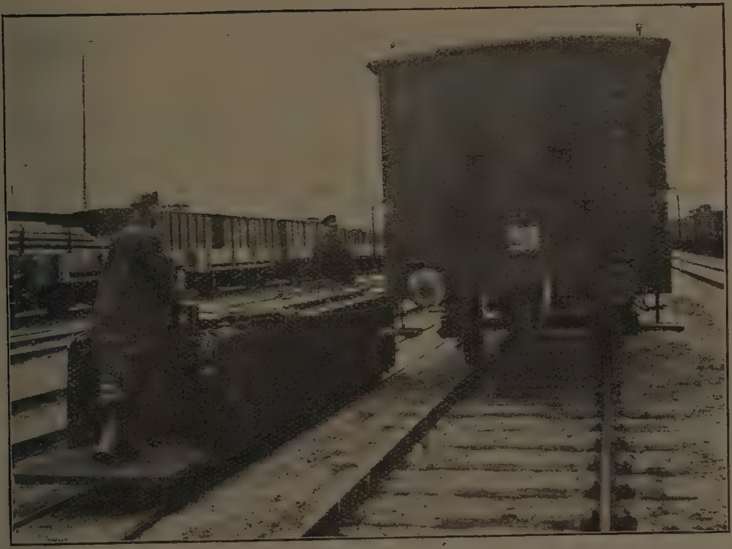


Fig. 34. — Tractor in operation.

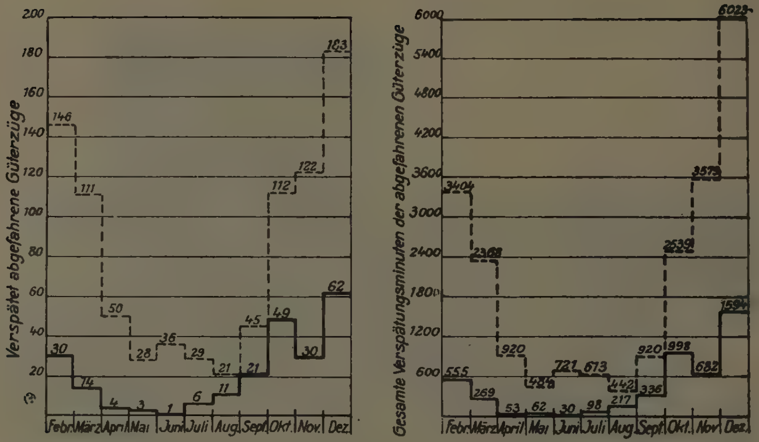
shifts, or 6 344 locomotive hours; and at the same time a greater volume of traffic was negotiated. An hour's shunting service with the available heavy locomotives costs 15.15 Reichsmarks (compare table 5); it follows that the total saving effected amounts to 15.15×6 344=96 111 Reichsmarks.

A further saving of 793 eight-hour shifts of a shunting crew of four men has also occurred, giving an additional economy of 6 344 × 4 × 1.0 Rm. = 25 376 Reichsmarks.

The total annual saving, therefore, amounts to 121 487 Reichsmarks against which the working expense for running the tractor are as follows :

	Reichsmarks.
Interest 7 % on 167 818 Rm. .	11 473
Depreciation of tractor 3 % on 12 750 Rm.	383
Depreciation of rectifier 3 % on 3 489 Rm.	105
Depreciation of track, sheds, etc. 1 % on 140 134 Rm. . . .	1 401
Maintenance of tractor 10 % on 12 750 Rm.	1 275
Maintenance of rectifier . . .	400
Maintenance of accumulators .	3 000
Maintenance of track and sheds	1 024
Power consumption at 85 kw.-h. daily, at 7.5 Rpf. = 300 × 85 × 0.075.	1 913
Oil, etc.	100
Total	21 074

The service of the tractor does not entail any special expenditure, since the driver was taken from the existing shunters and it was not necessary to replace him.



– – – – Values for 1927, *before* installing tractor.

— Values for 1928, *after* installing tractor.

Fig. 35. — Delays to outgoing trains *before* and *after* installing tractor at Rothensee.

Explanation of German terms: Verspätet abgefahrene Güterzüge = Departing goods trains delayed. — Gesämte, etc. = Total number of minutes outgoing goods trains were delayed.

A clear saving of approximately 100 000 Rm. annually has, therefore, been effected by the installation of the auxiliary closing-up equipment in Magdeburg-Rothensee.

This installation has improved the general working of the yard to an extraordinary extent; figure 35 shows a comparison between the delays in completing trains before and after the equipment was set to work on 1 February 1928.

[625. 23]

REPORT No. 4

(Germany)

ON THE QUESTION OF ALL STEEL COACHES. COMPARISON WITH VEHICLES BUILT OF WOOD (SUBJECT VIII FOR DISCUSSION AT THE ELEVENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION) (¹),

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(German State Railway Company).

Figs. 1 to 20, pp. 639 to 657.

This report is based on the questionaire of Messrs. Lancrenon and Vallancien, the reporters on the same subject for other countries. It should be clearly explained that the following discussion mainly represents the experience of the Reichsbahn (German State Railways), as in comparison with their total rail length which is in round figures about 53 000 km. (32 933 miles) with about 63 000 passenger coaches, the remaining privately owned railways play only a subordinate part, while in addition these railways build their stock on lines very similar to the types of vehicle constructed by the Reichsbahn.

The division of the existing passenger stock of the Reichsbahn does not depend on its service classification such as *suburban*, or *long distance*, but consists mainly of 4 groups, as follow :

1. Urban and suburban.
2. Passenger coaches for slow trains.
3. Coaches for fast trains.
4. Special fast long distance express train coaches.

For urban and suburban trains the coaches are carried on 2, 3 or 4 axles, according to the prescribed speeds of the trains; for ordinary passenger trains, most of the coaches have 2 or 3 axles, while for fast trains principally bogie coaches of light construction without vestibule corridor connections are used; for express trains, bogie coaches with 4 or 6 axles and through corridor connections are the rule.

That a large number of coaches having 2 or 3 axles still exists on the Reichsbahn is due to the former three and four-class system. The small units were very suitable for the traffic requirements then existing. Nowadays, since the introduction of the two-class system and the retention of the first class accommodation for special express trains only, the conditions for the construction of larger units are more favourable. The Reichsbahn therefore intends in the future to introduce four-axle bogie vehicles for the stopping passenger trains, and two-axle coaches will only be retained on lines

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(¹) Translated from the German.

carrying less important traffic. The construction of the specially designed bogie coaches for slow trains and for ordinary fast trains will be put in hand on a considerable scale as soon as the sample coaches have been tried out.

I. — Advantages of the all-metal method of construction.

When railway coaches were first constructed they were built of wood in accordance with the methods of manufacture known at that time and because of the small demands made on their strength. As speeds increased as well as acceleration at starting and deceleration when braking, it was necessary to reinforce certain highly stressed parts with steel and finally to replace them entirely by steel.

At first were made of steel the underframes of the ordinary 2 and 3-axle coaches on which, owing to their simple construction, the springs and axle guards were secured directly to sole bars.

Next came coaches for fast trains with bogies. The underframes of the German express train coaches still continued to be made of wood reinforced with steel. Body framing and panelling were also made of wood for all coaches.

In the next stage, while the wooden framing was retained, the wooden panelling of all German coaches with few exceptions was replaced by steel. This early method of construction, which was at first introduced into Germany, was retained for a long period; it was known, in the case of the ordinary passenger and fast train coaches with steel underframes running on 2, 3 or 4 axles, as the semi-steel type and for the wooden type with reinforced underframes as the wooden type.

The continual increase of the speed, of the length of the trains as well as the carrying capacity, called for a further increase of strength in the design. In consequence of the greater weight of the coaches the kinetic energy increased and with it the danger of the vehicles being broken up in case of accident. It was therefore decided to construct coaches in which all parts which had to come under stress of any kind should be of steel, rigidly connected by rivetting. This decision was moreover encouraged as a result of the shortage of hard woods in Germany and the increasing difficulty and expense in obtaining them from abroad. It was out of the question to use other and less expensive timber for the single piece pitch pine sole bars of the express train coaches. The fears that the replacement of wooden underframes and wooden body framing in express coaches by steel would cause a great increase of noise had to be ignored and efforts made by suitable design to reduce noise as far as possible.

The first steel coach for express trains (D. train coach) was put into service in 1912. This coach proved to be satisfactory apart from the few unavoidable defects which are to be found in any new design when tried out, and it was decided to revolutionize completely the design of German railway passenger coaches and to change over to the all-steel type of construction. Only the roofs were to continue to be made of wood because of the fear of excessive noise.

In 1927 steel was also introduced for roof construction, although as a result of their flat design they were inclined to be slightly noisy, and meanwhile a suitable design was arrived at by the use of double roofing.

The internal fittings of these all-steel coaches are up to date usually made of wood, both for decorative reasons and out of regard to the comfort of the traveller. Certain special designs were carried out for trial with steel partitions and without wooden fittings. One coach was also fitted up with interior furnishings made of a wood substitute. The tests of this new material have not yet been completed. They are however to be carried through as in view of the great difference in summer and winter temperatures it is hoped that the adoption of this material for interior fittings will offer considerable advantage to the passenger.

To sum up the following advantages are to be gained by the introduction and development of the all-steel passenger coach for the German State Railways :

1. — *Economic advantages.* — The sole bars required for building coaches of even medium length had to be bought from abroad at high prices. It can therefore not be said that the use of home made steel will cause an increase in the price of the vehicle.

Although the time has been too short to arrive at a definite conclusion by observation as to the life or the maintenance costs as compared with the wooden system of construction, everything points to the fact, that the all-steel vehicle will have a materially longer life and will have distinct advantages as regards maintenance. With the wooden type, both in the case of all wood and of composite designs, it was unavoidable that the joints, even with the greatest care in erection, should in course of time become loose, principally on account of the lesser permanence of wood and such construction therefore requires more careful watching.

2. — *Technical advantages.* — Methods of construction peculiar to the material employed (such as morticing), which demand very accurate workmanship and even then are not proof against slacking off, can now be avoided. The distribution of stresses over the complete structure can be more readily arranged in an all-steel structure. It is therefore easily possible to increase the length, breadth and the height of the coaches and in this way provide greater comfort for the traveller.

The Reichsbahn has by the change to all-steel construction, ceased to consider the underframe as the sole load-carrying member and has made use of the sides with their rivetted panels in such a way as to assist in the work of support. In this way it is hoped to develop a design which will not only increase the strength of the vehicle but will result in important savings in weight.

3. — *Greater safety of the passengers.* — The greatest advantage of the all-steel type as compared with that of wooden construction lies in the much greater strength and consequent safety of passengers in case of accident. Steel has, weight for weight, up to 30 times the strength of wood and steel construction must therefore offer the greatest possible security against destruction. The extent and value of this advantage has been clearly demonstrated in the accidents which have taken place in Germany in recent years.

In this respect the steel coaches have come fully up to expectations. Whereas in the case of several bad accidents, wooden coaches have been the cause of serious loss of life owing to the coaches telescoping, the steel coaches in the same accidents suffered relatively slight damage and protected the passengers riding in them from serious injury.

Even if there were no advantages but rather disadvantages to be accepted in connection with steel coaches, the above facts alone should lead to a decision in favour of steel construction. The same conclusion must be reached, when it is realized that the railways in consequence of the steadily growing competition from other means of transport, may eventually have to increase the speed of their trains.

Any disadvantages which at present exist will be got over by improving the design of the steel stock and, as in bridge construction, the use of wood for all parts subject to stress will be discontinued in coach construction.

II. — Types of coach in service, in construction or being designed.

As mentioned above the Reichsbahn put the first trial all-steel coach into service in 1912. The railway thereupon took up all-steel construction without restriction and continued to study design in order to still further perfect existing types of vehicle and in order to remove any defects which still exist, or which may still come to light.

The principle on which wooden coaches were formerly built, namely of fitting the underframes of long coaches with trusses and making them to stand the stresses due to buffing impact, to carry the weight of the body as well as the load due to the weight of the passengers etc., had already to a certain extent been departed from before the introduction of steel construction. The wooden body framing was stiffened by struts, reinforced with steel and was thus able to resist vertical stresses. The trussing of the underframes could not be done away with as a result of the above modification, not even when the underframe was made of steel so long as timber was still used for the body frame work.

It was only when all-steel construction was introduced that it was considered, especially in view of possible accidents, that one should not be satisfied with a highly resistant underframe carrying a much lighter body on it. Hence the side walls were developed as part of the weight carrying girder construction so that the body of the coach became part of a uniform whole. Naturally the underframe still had to be strong enough to resist the horizontal impact stresses; but the vertical stresses were now to be borne as far as possible by the sides alone. The aim was to produce a system having unbroken resistance to stress, on the one hand between the underframe and the sides of the body and on the other between the sides of the body and the roof. The sheet steel panels securely rivetted to the underframe, to the framework of the body and to the roof, was intended to function as a diagonal stiffening. Under this development, by which the side walls form part of the main girder it becomes feasible, even in the construction of long coaches, to do away with trussing. This method of construction must show to considerable advantage as compared with the designs adopted by other Railway Authorities under which all horizontal and vertical stresses are taken by a suitably designed underframe having a light coach body mounted on it. With the same weight, greater strength is achieved or with equal strength a saving in weight becomes possible. Even without any special buffing arrangements in the end walls of the coaches, the danger of telescoping is considerably reduced.

The pillars of the sides formed of Z bars are rivetted to the outside of the solebars or longitudinals of the underframe and at their upper ends to a stiff longitudinal rail made of Z and L bars forming part of the roof framing and running from one end wall to the other (fig. 1).

A further longitudinal tie is provided by connecting the pillars by means of angle bars below the level of the window sills in addition to which a stout bar of flat iron is rivetted on over the steel body sheets. The sheets forming the body panels are themselves rivetted to the framework of the body, thus forming an extremely stiff supporting frame. The body sheets are flanged inwards around the window frames. The connection between the body sheets and the solebars is made by means of Z bars. The roof frame is built up of curved Z bars and with flat iron carlines. The plain curved roof which is now being introduced shows to special advantage as compared with the old type with clerestory and ventilators, both as regards construction as well as maintenance. This is principally due to the elimination of those portions of the clerestory and ventilators which were very apt to become leaky. A view of the

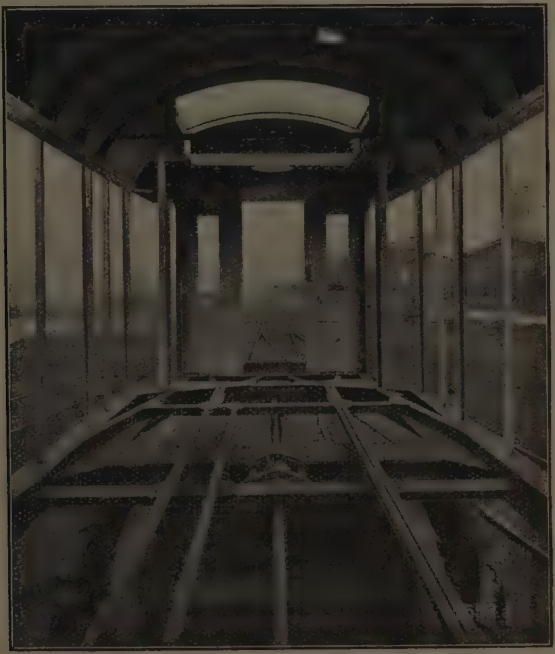
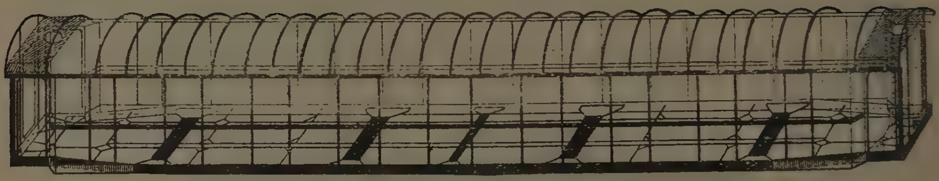


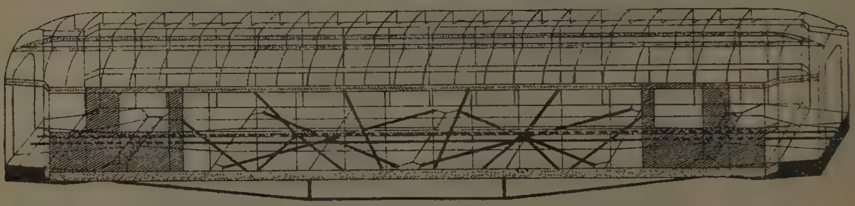
Fig. 1. — Body frame work and buffer beam for an all-steel express train coach.

All-steel coach for express trains.



Roof and side panelling of sheet steel.

Wood coach for express train (former standard type).



▬ } Weight-carrying steel structural parts in steel and wooden coaches.

▨ Reinforcing steel plates in side wall of wooden coach and anti-telescoping end walls of steel coach.

▤ Wooden beam in wooden carriages.

Fig. 2.

replacement of wood by steel on express coaches is shown in figure 2.

Only a few all-steel 2-axle compartment coaches with side doors have been built experimentally. In general the design with the doors at the ends of the coaches is most favoured both in the case of the 2 and 4-axle slow and fast train coaches as well as for the 4-axle coaches for express trains (express train coaches). This also applies to two-axle coaches both with open and closed platforms. The design with open platform will shortly be discontinued because closed platforms or vestibules give better protection in case of accident to passengers seated in the compartments.

The end walls of the vestibules are specially strengthened to prevent telescoping by the adoption of the so-called « ram construction » (see fig. 3).

Heavy angle irons are carried up from the underframe to the roof at the corners and in addition at both sides of the door. They are firmly rivetted to both members and are further stiffened by special pieces mounted over the top edge of the end door.

This ram construction is designed in every case to meet the maximum speed at which each type of coach is expected to run and is so carried out that in case of accident only the vestibule will be crushed while the passenger space beyond it will remain undamaged. Rigid, inelastic stiffening pieces have been avoided because the protection against heavy impacts would cease to exist once the rivets connecting the parts had sheared. The kinetic energy liberated when a collision takes place must be absorbed by allowing it to expend its force on the elastic ram construction. As already mentioned above this method of construction has already proved its value even in the severest accidents.

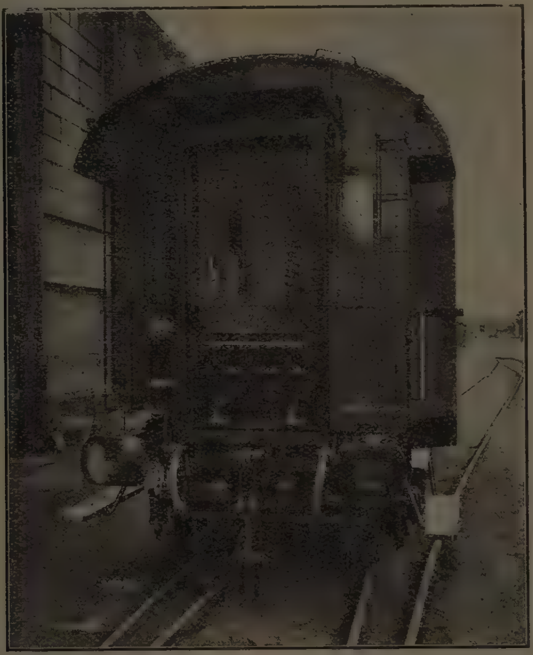


Fig. 3. — End wall of steel express train coach.

In addition to these designs having entrances through vestibules at the ends of the coaches, all-steel coaches have been built for urban and suburban lines (Metropolitan of Berlin and express motor coaches) with several side and center doors. The door openings are stiffened by means of strong portal frames, so that in this case also the sides of the coach are built to resist the vertical stresses. The constructional features of the various types are shown in figures 4 to 10.

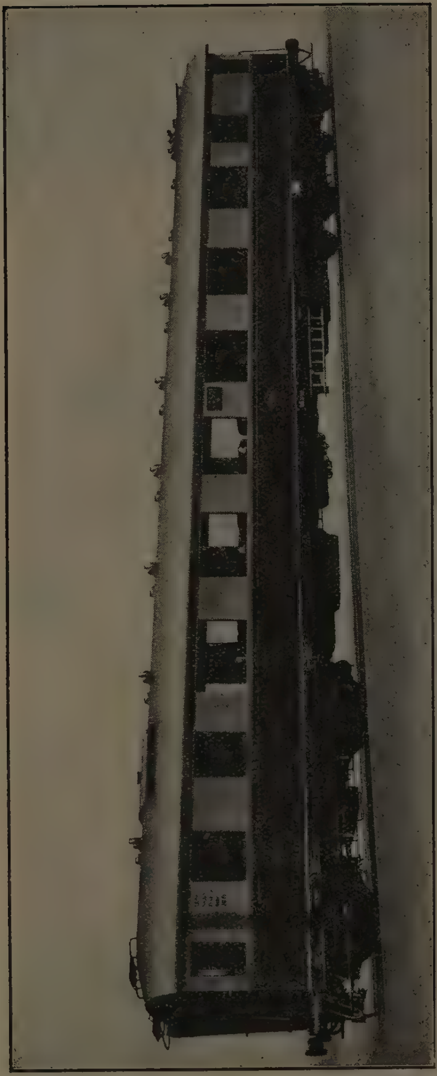


Fig. 4. — All-steel coach for « Rheingold » train.

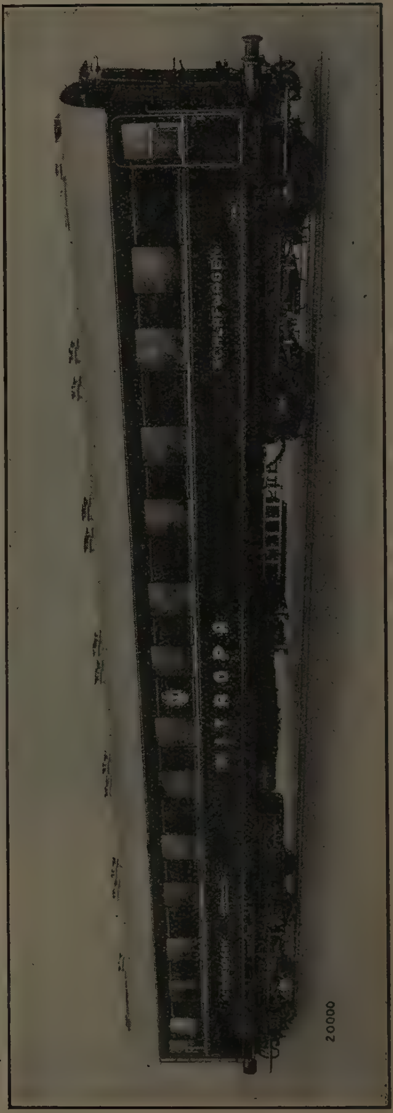


Fig. 5. — Steel sleeping car for « Mitropa » Express.

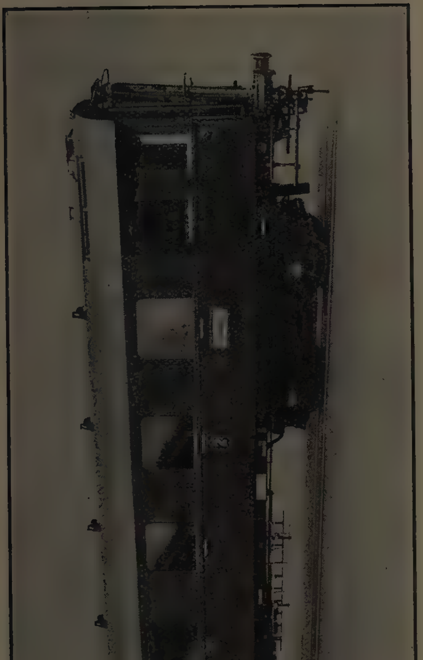


Fig. 6. — Steel coach for express trains.

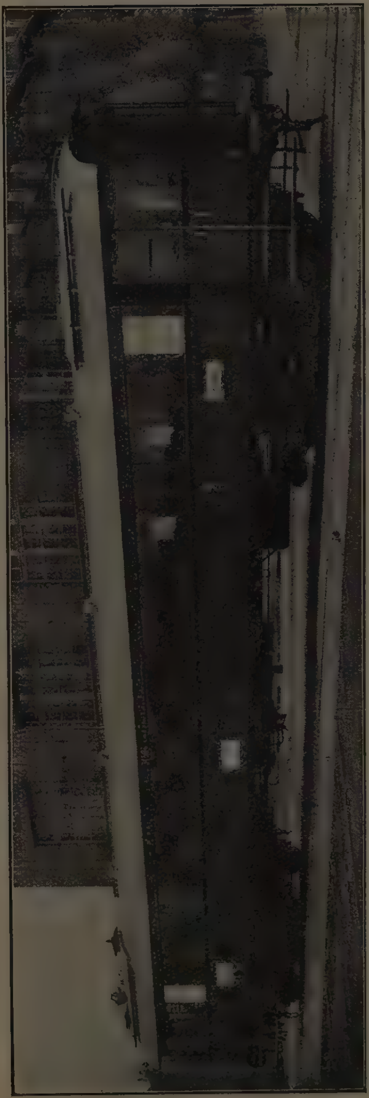


Fig. 7. — Steel coach for fast and slow trains.

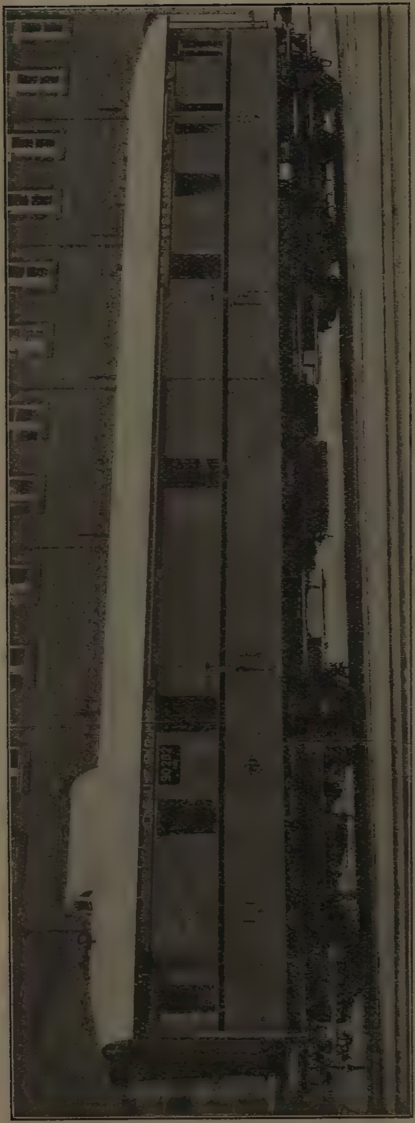


Fig. 8. — Steel luggage van.

III. — Construction and materials.

The aim of the Reichsbahn is to use as far as possible standard rolled sections and sheets. For the body frame preference is given to Z section bars which facilitate construction in some respects. Larger pressings are avoided where possible because it is difficult to secure complete interchangeability for repair work. Pressed and stamped plates are only used for covering purposes, while malleable cast iron and steel castings are only used for fittings and mountings. Pressed steel sections were used wherever possible for experimental purposes on certain coaches instead of rolled sections. But this method of construction was not generally used because the advantages of saving in weight were offset by greater difficulties in maintenance.

The floors are made of two thicknesses of wood. They are made in one or two sections held in strong frames and secured to the finished underframe by means of screwed bolts.

Light metals have so far been little used in Germany. Ventilating cowls, feet for seats and brackets for parcel nets have been made experimentally of silumin. The first serious attempt to use light metals can be seen in the construction of the multiple-unit trains of the Berlin Metropolitan which are being built by the Wegmann Waggonfabrik in Kassel, and Messrs. Busch in Bautzen, in which « *Lautal* » rolled sections and silumin castings are being used. In these coaches only the bogies, the solebars and the main cross bearers are of steel, while all other parts including partitions are carried out in light metal. The object is to try out, on these trains, to what extent the use of such expensive materials is justified on passenger stock subject to heavy wear. In addition to this experiment, the Coach

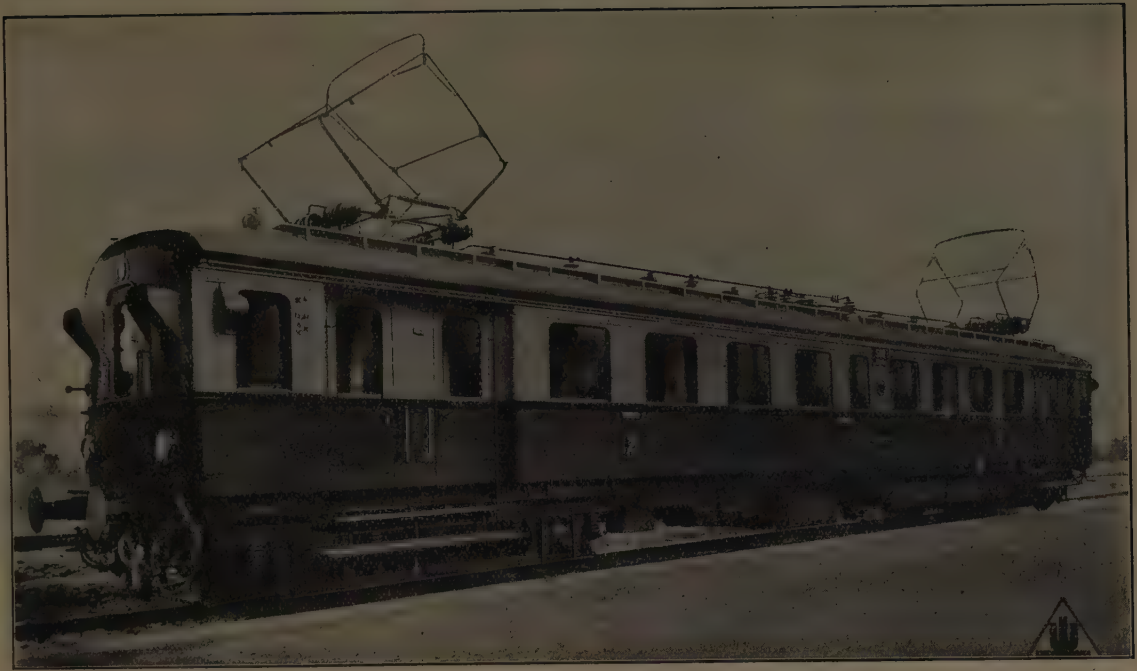


Fig. 9. — Steel motor coach running on alternating current.

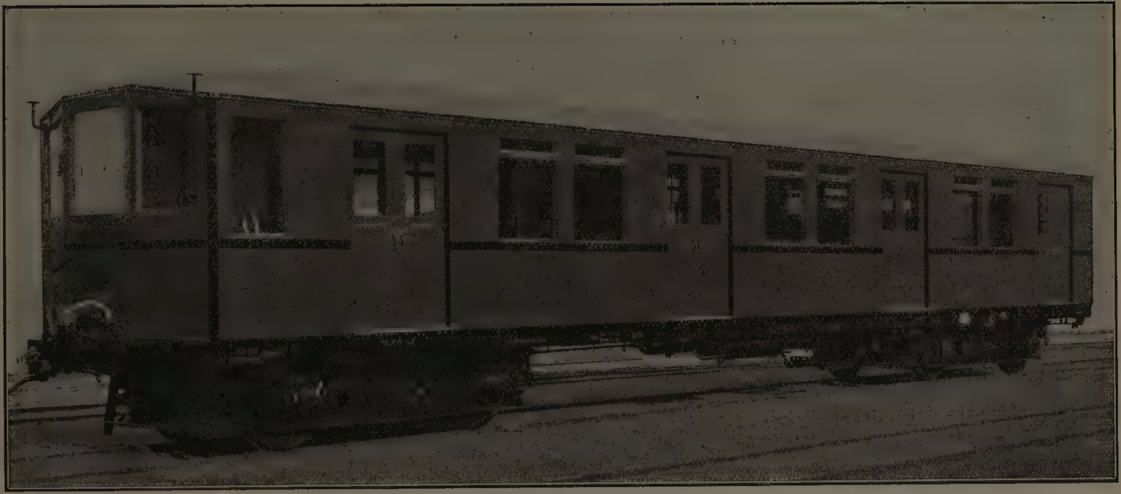


Fig. 10. — Steel D. C. motor coach for the Berlin Metropolitan Railway.

Building *Uerdingen* Works have built a specially light motor coach for one of the German private railway companies. Results as to the behaviour of this coach are not as yet available.

The German passenger coaches are at present exclusively put together by rivetting. Rivets up to 8 mm. (5/16 inch) in diameter are closed cold; above 8 mm. they are put in hot. Coaches built of light material are likewise rivetted with rivets of the same material.

Small rolled sections and rods are usually assembled together by the electric welding; the body sheeting and the roof are welded by oxy-acetylene. The body sheets have been experimentally connected to the framing by spot welding. These different methods of welding have proved satisfactory in practice. Tests of the breaking strength of material have shown in the majority of cases that the fracture does not take place at the weld. The results led the Reichsbahn to place an order with the *Görlitz* Waggonbau- und Maschinenfabrik for one of their design of bogies, put together entirely by welding without any rivets at all (see fig. 17). Before the bogies were finally constructed, sample welds were made of the different joint connections, gussets, etc., and these were tested for strength to ascertain whether electrically welded joints could be expected to have at least equal strength as compared with the connections formerly made with rivets. A saving in weight of about 5 % as compared with the rivetted bogie truck was secured, while at the same time the strength of the individual welds was entirely satisfactory. This bogie is now being out into service and will be kept under observation. These parts (bogies) which are subject to the greatest stresses were chosen for the welding trials, because one would in this way, obtain with the least delay an idea of the actual value of this method of construction for coach building.

The rivetting of the outer panels of the coach is partly carried out with ordinary cup headed rivets and partly with countersunk flush rivets. Rivetting with cup heads has the advantage that for repair work the seams and connections can be more easily cut apart. Countersunk rivets on the other hand have to be drilled out. As against this the countersunk rivetting gives the coach body a cleaner appearance. Painting and cleaning is facilitated. Dirt lodges first round the exposed rivet heads, and with poor workmanship, corrosion will be more readily started. Thin plates cannot be assembled with countersunk rivets because they would not have sufficient hold. In order to give a good artistic finish for the exterior it may be possible to use sufficiently large mouldings to cover the joints and thus meet the objections raised at the present time against the countersunk rivet. However, a conclusive opinion on the suitability of the two methods of rivetting for passenger coaches cannot as yet be formed because the time has been too short to observe their behaviour. Should no injurious effects come to light in connection with countersunk rivetting, this method would be given the preference by the Reichsbahn.

Wood is still retained for use in partitions, floors and the lining of walls. Instead of the match board lining which was formerly employed, plywood is now largely employed, because, provided it is properly fitted it is very little affected by climatic influences and, because of its unbroken surface, it has a better appearance. The steel roof is also frequently provided with a wooden lining.

The new coaches are generally finished

on the outside with lacquer. The internal partitions are partly polished with shellac polish or are spray-painted with nitro-cellulose and then polished. To prevent corrosion of the inner sides of the panelling and the steel framing a protective coating made from red lead is given.

IV. — Internal fittings.

Although the Reichsbahn uses steel to a great extent for the construction of new coaches and employs this material exclusively where shock and load stresses have to be borne by the respective parts, they have not yet been able to reach a decision as regards the replacement of wooden internal fittings by steel. The danger in case of accidents, of injury to passengers by splinters or by fire has already been very considerably reduced by the introduction of all-steel construction. On the other hand wooden fittings lend themselves much better to artistic effect and passengers find their stay in the coaches more agreeable. The very high conductivity of steel fittings causes them to be covered with condensed moisture in the event of heavy falls in temperature. Such condensation has unpleasant results for the passenger touching the damp fittings.

In the first class compartments of the new express passenger coaches, mahogany panelling is exclusively used. In the second, the partitions are covered with granitol or pegamoid framed in walnut. In the third class the wood sheathing is painted with a light paint.

The inner roofs of the de luxe coaches and of the first class vehicles are finished with polished wood panelling. The roofs of other classes are made of wood, compo board or metal painted white.

The corridors are finished to match the finish of the various classes. Opposite the first class compartments the corridor walls are covered with fabric. The frames of the panels are made of mahogany. Opposite the second class sections the walls above the waist rail are granitol or pegamoid covered, while below the waist rail green linoleum is used. The walls opposite the third class are wood sheated. The same practice is applied to the vestibules which conform to the corridors or the compartments (figs. 11 to 15).

For lavatories a covering of linoleum has been selected finished in white varnish finish (fig. 16). Further trials are being made with coverings of enamelled zinc.

The wooden floors in the passenger compartments, corridors and vestibules are covered with linoleum. The lavatories of the express train coaches are tiled, while in the other passenger coaches, the lavatory floors are, for the sake of weight, rendered with a coating of wood cement.

No special arrangements for ventilation, heating or furnishing were entailed by the all-steel construction. At first, corrosion of the inner sides of the steel panels was feared, but this was only to be found when those surfaces which were covered in and hidden from view were not thoroughly protected with anti-rusting composition and when sufficient ventilation was not provided. This last provision tends to cause a loss of heat, because of the absence of insulating air spaces. The increase of heating required is not however a serious matter because the wooden lining of the coaches acts as insulation. The double roof construction which has been adopted acts as a good insulator and also deadens the noise which would otherwise be caused by the steel sheets.

The wooden internal fittings of the

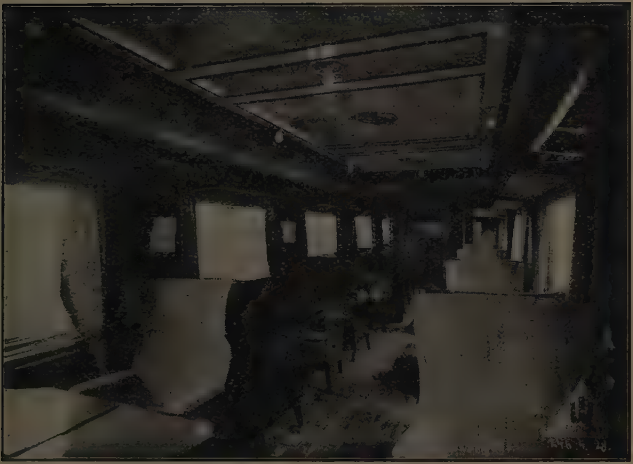


Fig. 11.
Interior finish of first class steel coach for « Rheingold » train.

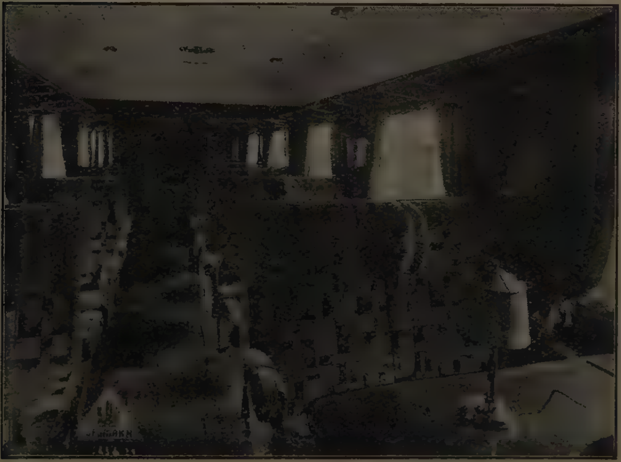


Fig. 12.
Interior finish of second class steel coach for « Rheingold » train.

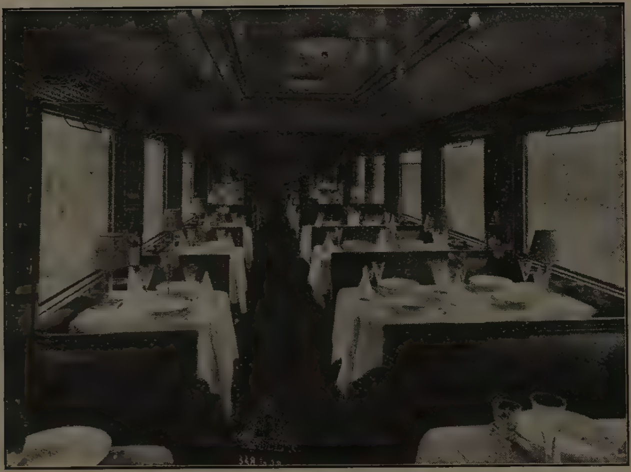
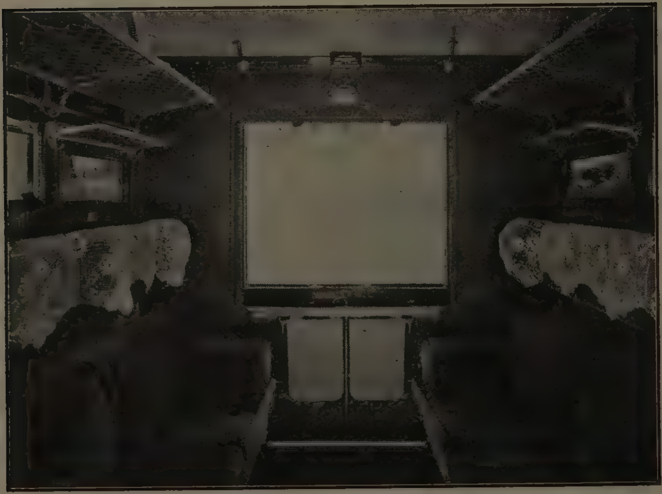


Fig. 13. — Interior finish of Mitropa dining car.



Fg. 14. — Interior finish of 1st class compartment.

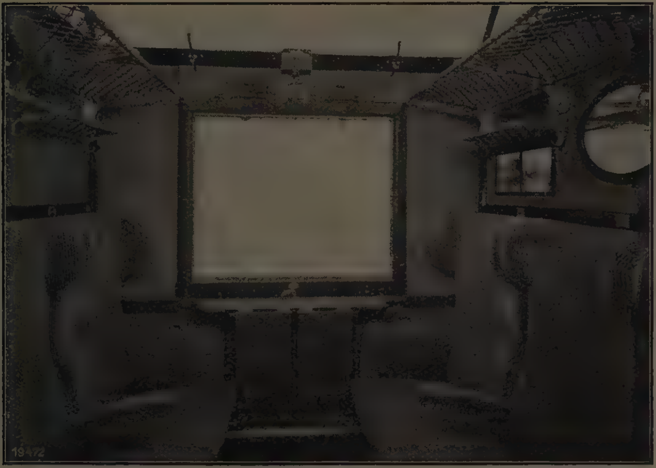


Fig. 15. — Interior finish of second class compartment.

coaches showed themselves also as effective in preventing noise. In the more expensive types of vehicle, a lining of felt introduced between the linoleum and the floor still further reduced the noise. To combat the effects of strong sunlight the outside of the roof is painted with aluminium paint. In addition numerous experiments are being conducted with insulating materials such as celotex, peat slabs and granulated cork. In comparison with uninsulated vehicles it was found that the effect on running vehicles, of such insulation was small, and the general introduction of these materials either for heat insulation or for noise reduction could be neglected for the present.

For ventilating, the usual arrangements such as Wendler and electric aspirators could be retained.

The slight remaining danger in case of accident from fire and splinters in coaches with wooden internal fittings, is being met by the general introduction of electric lighting both for new and old vehicles as also by the greatest possible use of plywood. As already stated, experiments are being conducted with a new material which has the desirable qualifications of wood, but is said to be incombustible and non splintering. As this material consists of a wood aggregate it will work easily.

The stiffness of the vehicles would undoubtedly be improved if all openings in the steel roof could be avoided both for ventilators as also for water tanks. In the case of water tanks, difficulties will arise so long as there are no arrangements on the German and other lines over which the coaches travel, for filling the water tanks from below. Access is obtained to the tanks by means of openings in the roof closed by cover plates. When these plates are removed the tanks can be got at without trouble.

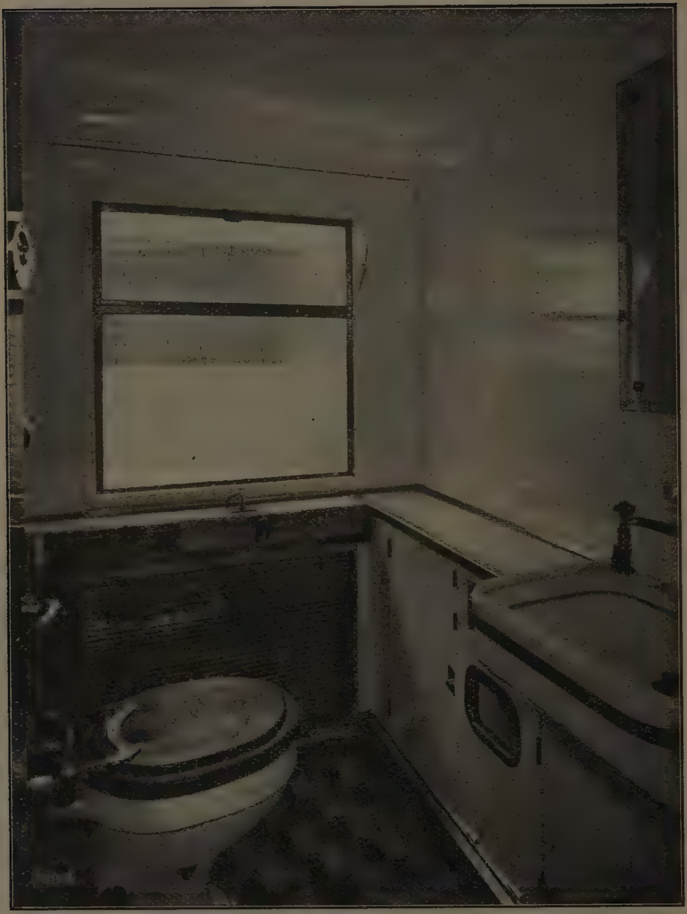


Fig. 16. — Interior finish of a lavatory.

V. — Comparison with wooden coaches.

The all-steel coaches are, as has already been shown, much stronger than wooden vehicles and if properly designed can be made appreciably lighter. In case of accident they are superior to the wooden vehicles, because the combination of the underframe, body and roof offers such resistance to impact stresses that dangerous results cannot take place as in the case of the wooden vehicle. On account of its elasticity, steel will absorb far more impact without being entirely broken up. Danger from fire is also considerably reduced.

When the arrangement and fitting up of the steel coach is compared with that of the wooden vehicle, it must not be forgotten that with the introduction of all-steel construction, the length, width and height of the vehicle has been increased to the permissible limit in order to give the passengers the greatest possible comfort. It must also not be overlooked that the internal arrangements have in part been greatly improved. Better bogies, larger accumulators, and water tanks with much greater capacity have been installed and the draw, buffing and brake gear, all of which have nothing to do with steel construction, have been strengthened and improved.

The table, Appendix I, gives details of new coaches both of all-steel and part steel construction as also of the later types of wooden coach which were built before the introduction of steel.

In comparing coaches of the same classes it will be seen, for example, that a first class steel coach (design A4ü No. 1) has a greater weight per seat, namely 1 062 kgr. (2 341 lb.) as against 1 048 kgr. (2 310 lb.) for the wooden coach (A4ü No. 15). But this slight increase in weight is only due to an increase of space available, which is a considerable improvement . The weight per linear metre has been reduced from 2 298 to 2 184 kgr. (1 544 to 1 467 lb. per linear foot) and, per square metre of floor surface from 881 to 822 kgr. (180.5 to 167.4 lb. per sq. foot), a substantial reduction.

In the first and second coaches (AB4ü Nos. 2 and 16 respectively) the weight per seat has been reduced from 1 107 to 1 000 kgr. (2 442 to 2 206 lb.), the weight per linear metre from 2 429 to 2 350 kgr. (1 632 to 1 579 lb. per linear foot) and the weight per square metre of floor space from 923 to 877 kgr. (189 to 179.6 lb. per sq. foot).

The conditions in the third class express coaches (C4ü Nos. 5 and 19) are equally favourable. In this case the weight per seat is only 588 kgr. (1 297 lb.) in the steel coach No. 5 as against 669 kgr. (1 476 lb.) in the wooden one. The corresponding weights per metre run are 2 302 kgr. as against 2 378 kgr. (1 547 and 1 598 lb. per linear foot) and per square metre 858 kgr. as against 885 kgr. (175.7 as against 181.3 lb. per sq. foot) A comparison of the steel and wood coaches with all-steel coaches of the same classes likewise shows considerable saving in weight. The all-steel second class coach (B4i No. 6) shows a weight per seat of 588 kgr. (1 297 lb.) as against 796 kgr. (1 756 lb.) for the steel and wood coach (No. 12). The weight per metre run is only 1 780 kgr. as against 2 137 kgr. (1 196 and 1 436 lb. per linear foot), and the weight per square metre of floor is only 773 kgr. as against 855 kgr. (158.3 lb. as against 175.1 lb. per sq. foot).

It is expected that these favourable results which have been obtained in the construction of the first designs for passenger coaches will be further improved when the designs have been thoroughly worked out, as also by the use of high tensile steel and cheaper light metals.

A comparison of the electric high-speed motor coaches and the new electric urban and suburban coaches of the Reichsbahn with the old type of wooden coaches is not possible, because coaches of this type were not at that time built of wood. It may however be stated that the advantage of steel construction is as great from the point of view of strength for coaches which have to carry the weight of electric equipment as it is for coaches which do not possess their own motor equipment.

The fact must also not be overlooked that the new passenger coaches of lighter weight are suitable for running at higher speeds than those hitherto designated as maximum speeds, whereas the wooden coaches may be said to have reached their safe limit as regards running speed. With an increase of speed they would be unequal to the stresses which arise, thus endangering the safety of the passengers and incidentally cost of maintenance would become excessive.

It should be mentioned that the Reichsbahn at the same time that it introduced the all steel construction, adopted a new type of bogie truck after many trials with different designs. This new bogie truck is said to result in smooth running and at the same time has special advantages from the point of view of maintenance work in the repair shops and in service on account of its simplicity. The springs are principally laminated springs, the reason being that this type of spring has been proved experimentally to be the most suitable for taking up shocks, while the friction between the plates gives the desired damping out of impact action and rebound. The two types of bogie truck for express and slow trains are shown in figures 17 and 18.

Both types of bogie have the peculiarity that the adjustment of the spring hangers for the purpose of correcting the buffer height does not affect the fixed bogie bolster hangers which are set to give smooth running, or the forces which tend to center the coach on the bogie.

As already mentioned, the change over from wood to steel construction for coaches of the Reichsbahn involves no increase in the weight of any particular unit. Apart from the fact that the cost of wages and of materials has increased, as has been the case everywhere in Germany since the war, it is established that the transition to steel in Germany has not entailed any increase in the price of passenger stock; on the contrary, the relative price per unit has fallen.

The following table shows the number of steel passenger coaches built up to the first of January by the German State Railways.

Express train coaches.		
A 4 ü	=	34
AB 4 ü	=	300
ABC 4 ü	=	70
B 4 ü	=	38
C 4 ü	=	481
Pw 4 ü	=	207
Pw Post 4 ü	=	20
Total:		1150

Fast and slow-train coaches.		
B 4 i	=	4
BC 4 i	=	24
C 4 i	=	41
B i	=	1697
BC i	=	974
C i	=	2883
B	=	10
BC	=	40
C	=	1153
Pwi	=	744
Total:		7570

Motor coaches and trailers.		
e a T	=	18 (double coaches)
v T	=	56
e l T	=	86 (52 Jacob coaches)
e l (trailer)	=	18
e s T	=	676
e s (trailer)	=	682
Total:		1536

In all 10 256.

In the above tables only the principal models are shown. Modifications of the principal types are counted among those types.

In addition to the plans shown in appendix 2, there are, in appendices 3 to 5, a few sketch arrangements of the construction of steel coaches for express trains.

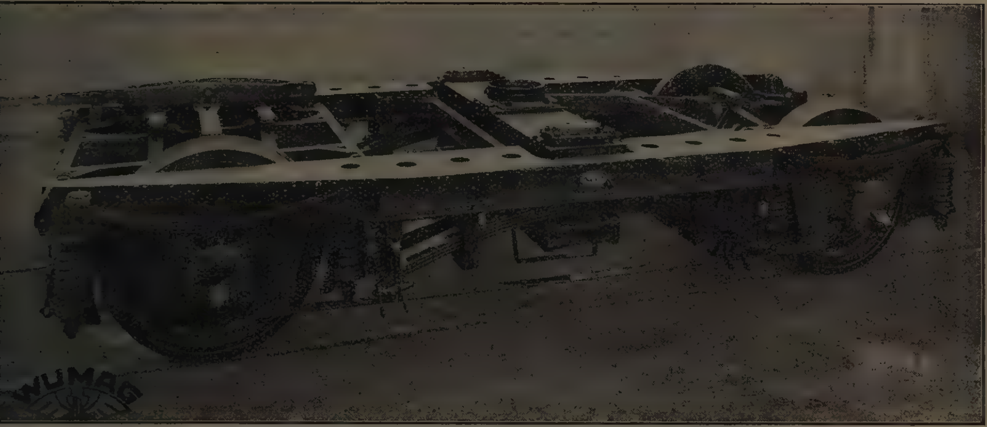


Fig. 17. — Görlitz patent bogie truck No. 2 for heavy express coaches. — Welded experimentally.

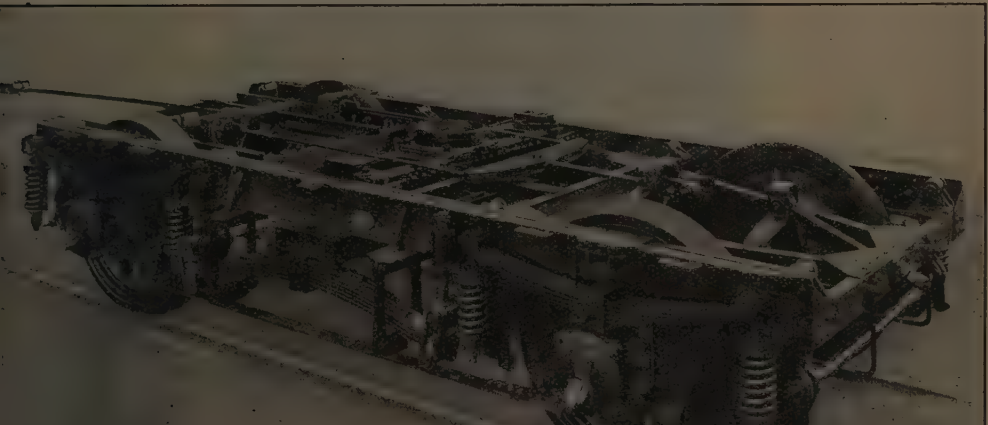


Fig. 18. — Görlitz patent bogie truck No. 3 for light fast and slow train coaches.

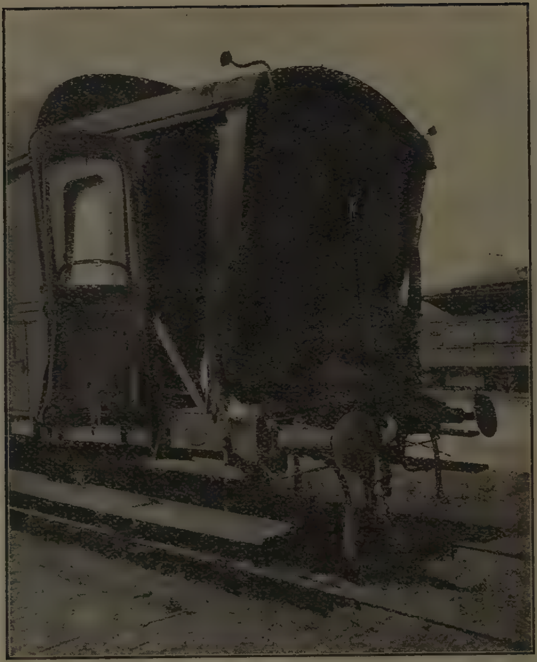


Fig. 19. — Luggage van end damaged in collision.

VI. — Results in service.

The time for observing the behaviour of the coaches in service is still too short to form a final opinion. It has however been established that as regards smooth running, noiselessness, and possibilities of insulation, the steel coaches do not show any disadvantages as compared with the old wooden vehicles.

The advantages are particularly important in the case of accidents which are unfortunately not entirely avoidable in railway working. It has been definitely established that in the collisions and derailments which have occurred in late years, the steel coaches have protected the passengers much more efficiently than the wooden coaches which formed part of the same train, because where the latter frequently telescoped, the steel coaches only suffered deformation on the ends. Figures 19 and 20 illustrate the damage suffered by the steel coaches.

As has already been mentioned, the maintenance costs of steel coaches must be less than with the wooden ones. While it is possible that in the event of slight

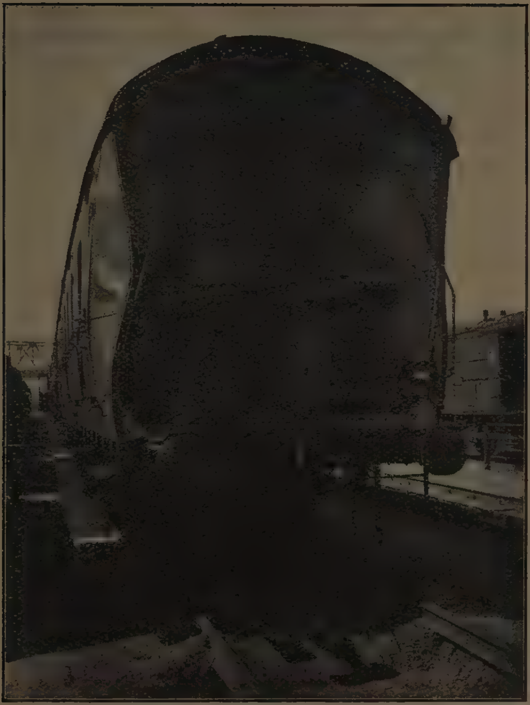


Fig. 20. — Coach end damaged in collision.

damage the cost of repairs to the steel coach will be higher because it may be more difficult to replace some individual part of the structure in the bogie, body, frame or panelling, there is no question that the ordinary wear and tear in normal working will require substantially less maintenance in the case of the steel coaches. If is of course understood that the methods of maintenance are modified to suit the new materials.

I would like to close my report with an expression of thanks to the coach building establishments which have collaborated in the development of steel in coach construction and which were most obliging in placing at my disposal for the purpose of this report details of their own experiences and I should like to express the hope that steel construction of railway coaches will continue to be introduced and further developed in other countries for the benefit of the travelling public.

Table of recent all-steel, semi-st

Plan.	Classification.	Year built.	Length in metres (in feet and inches).			Inside dimensions of body in metres (in feet and inches).		
			Over buffers.	Over body.	Maximum height above rail.	Length.	Width.	Heigh
								A. — All-st
1	A4ü	1926	21.720 (71'3")	20.420 (67'0")	3.993 (13'1 3/16")	20.355 (66'9 3/8")	2.750 (9'1/4")	2.50 (8'2 7/
2	AB4ü	1928	21.720 (71'3")	20.420 (67'0")	3 993 (13 1 3/16")	20.277 (66'6 5/16")	2.770 (9'1")	2.50 (8'2 7
3	ABC4ü . . .	1929	21.720 (71'3")	20.420 (67'0")	3.993 (13'1 3/16")	20.277 (66'6 5/16")	2.770 (9'1")	2.50 (8'2 7/
4	B4ü	1922	20.610 (67'7 3/8")	19.310 (63'4 1/4")	3.993 (13'1 3/16")	19 241 (63'1 1/2")	2.786 (9'1 3/4")	2.64 (8'8 3/
5	C4ü	1928	21.720 (71'3")	20.420 (67'0")	3.993 (13'1 3/16")	20.277 (66'6 5 16")	2.770 (9'1")	2.50 (8'2 7/
6	B4i	1929	21.790 (71'5 7/8")	20.490 (67'2 3/4")	3.993 (13'1 3/16"	20.360 (66'9 9/16")	2.838 (9'3 3/4")	2.55 (8'4 5/
7	BC4i.	1929	21.196 (69'6 1/2")	19.896 (65'3")	3.993 (13'1 3/16")	19.766 (64'10 3/16")	2.834 (9'3 19/32")	2.55 (8'4 5/
8	C4i	1929	20.960 (68'9 1/8")	19.660 64'6"	3.993 (13'1 3/16")	19.530 (64'1")	2.867 (9'4 7/8")	2.55 (8'4 5/
9	Bi	1928	14.040 (46'1 13/16")	12.740 (41'9 9/16")	4.007.5 (13'1 3/8")	12.610 (41'4 1/2")	2.970 (9'9")	2.57 (8'5 7/1
10	BC4	1928	13 920 (45'8")	10.820 (35'6")	4.007.5 (13'1 3/8")	10.639 (34'10 7/8")	2.940 (9'7 3/4"	2.57 (8'5 7/
11	Ci	1928	13.920 (45'8")	10.820 (35'6")	4.007.5 (13'1 3/8")	10.639 (34'10 7/8")	2.940 (9'7 3/4)	2.57 (8'5 7/
								B. — Steel-wo
12	B4.	1919	19 200 (63'0")	17.500 (57.5")	3.977 (13'5/8")	17.360 (56'11 1/2")	2.520 (8'3 1/4")	2.61 (8'6 3/
13	BC4	1905	18.550 (60'10 5/16")	16.850 (53'3 3/8")	3.977 (13'5/8")	16.710 (54'9 7/8")	2.470 (8'1 1/4")	2.61 (8'6 3
14	C4	1919	19.200 (63'0")	17.500 (57'5")	3.977 (13'5/8")	17.360 (56'11 1/2")	2.520 (8'3 1/4")	2.61 (8'6 3/
								C. — Wood
15	A4ü	1913	20.450 (67'1 1/8")	19.150 (62'10")	4.060 (13'3 7/8")	19.000 (62'4"]	2.700 (8'10 5/16")	2.7 (8'10 3
16	AB4ü	1915-19	20.350 (66'9 3/16")	19.140 (62'9 1/2")	4.060 (13'3 7/8")	18.990 (62'3 11/16")	2.730 (8'11 1/2")	2.7 (8'10 3
17	ABC4ü	1909/10	19.775 (64'10 1/2")	18.490 (60'8")	4 060 (13'3 7/8")	18.340 (60'2")	2.790 (9'1 7/8")	2.7 (8'10 3
18	BC4ü	1914/20	20.350 (66'9 3/16")	19.140 (62' 9 1/2")	4 060 (13'3 7/8")	18.990 (62'3 11/16")	2.790 (9'1 7/8")	2.7 (8'10 3
19	C4ü	1913/20	20.350 (66'9 3/16")	19.140 (62'9 1/2")	4.060 (13'3 7 8")	18.990 (62'3 11/16")	2.790 (9'1 7/8")	2.7 (8'10 3

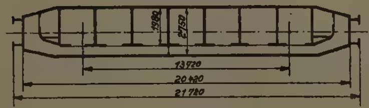
wooden coaches.

r area n m² square eet).	Light weight in metric (in English) ons.	Bogie		Seats.			Weight in kgr. (in pounds).		
		Type.	Weight (in kgr.) (in lb.)	1st. cl.	2nd. cl.	3rd. cl.	per linear metre (per linear foot)	per seat.	per m² (per square foot) of floor surface.
icles.									
4.24 33.8)	44.6 (43.9)	American	6 250 (13 779)	42	...	..	2 184 (1 467)	1 062 (2 341)	822 (108.6)
4.75 39.3)	48 (47.2)	Görlitz	7 270 (16 028)	12	36	...	2 350 (1 579)	1 000 (2 205)	877 (179.6)
4.75 39.3)	46 (45.3)	Do.	7 270 (16 028)	6	18	40	2 253 (1 514)	719 (1 585)	840 (172.0)
1.92 58 8)	41 3 (40.6)	American	7 270 (16 028)	48	..	...	2 139 (1 437)	860 (1 896)	795 (162.8)
4.75 39.3)	47 (46.3)	Görlitz No. 2	6 250 (13 779)	...	...	80	2 302 (1 547)	588 (1 296)	858 (175.7)
9.80 36.0)	36.5 (35.9)	Görlitz No. 3	7 270 (16 028)	...	62	...	1 780 (1 196)	589 (1 298)	733 (150.1)
4.38 85.3)	37 (36.4)	Do.	5 500 (12 125)	...	31	42	1 860 (1 249)	507 (1 118)	680 (139 3)
3.36 74 4)	34.8 (34.3)	Do.	5 500 (12 125)	...	...	86	1 770 (1 189)	405 (893)	652 (133.5)
5.78 85.1)	20.2 (19.9)	...	...	...	38	...	1 586 1 066)	532 (1 173)	565 (115.7)
1.28 36.7)	20.5 (20.2)	...	...	...	15	34	1 895 (1 273)	418 (922)	655 (134.1)
1.28 35.7)	20.6 (20.3)	...	...	...	...	58	1 904 (1 279)	355 (783)	659 (135.0)
icles.									
3.75 70.9)	37.4 (36.8)	American	6 250 (13 779)	...	47	...	2 137 (1 436)	796 (1 755)	855 (175.1)
1.28 44.3)	34.5 (34.0)	Prussian	6 100 (13 448)	...	20	45	2 047 (1 375)	507 (1 118)	836 (171.2)
3.75 70.9)	36.5 (35.9)	American	6 250 (13 779)	...	...	76	2 086 (1 402)	480 (1 058)	834 (170.8)
icles.									
9.96 37.8)	44 (43.3)	American	6 250 (13 779)	42	...	...	2 298 (1 544)	1 048 (2 310)	881 (180.4
0.37 42 2)	46 5 (45.8)	Do.	6 250 (13 779)	12	30	...	2 429 (1 632)	1 107 (2 441)	923 (189.5)
9.45 32.3)	42.5 (41.8)	Do.	6 250 (13 779)	6	15	32	2 299 (1 545)	802 (1 768)	859 (175.9)
1.46 53.9)	40.5 (39.9)	Do.	6 250 (13 779)	...	18	40	2 116 (1 422)	698 (1 539)	787 (161.2)
1.39 53.2)	45.5 (44.8)	Do.	6 250 (13 779)	...	...	68	2 378 (1 598)	609 (1 475)	885 (181.3)

APPENDIX II.

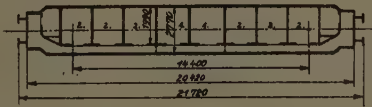
Diagrams of the coaches mentioned in the table, Appendix 1.

1.



A4ü

2.



AB4ü

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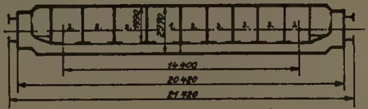

ABC4ü

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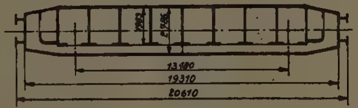

B4ü

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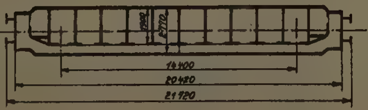

C4ü

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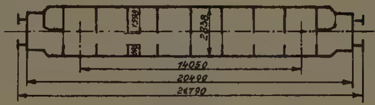
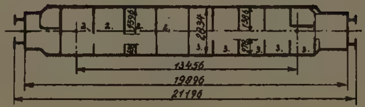


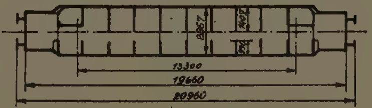
B4i

7.



BC4i

8.



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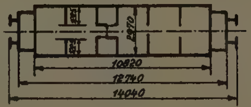
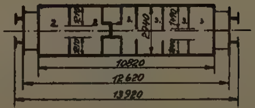


Bi

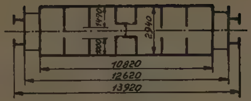
10.



BCi

APPENDIX II (*continued*).

11.



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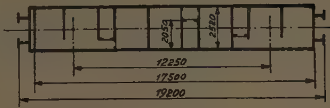
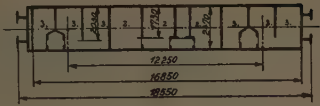


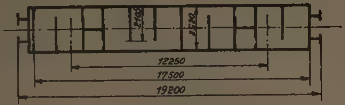
B4

13.



BC4

14



C4

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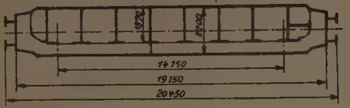
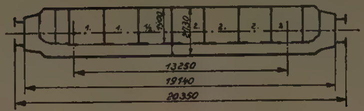


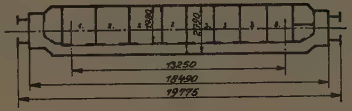
A4ü

16.



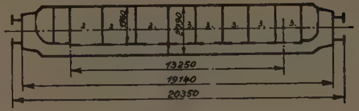
AB4ü

17.



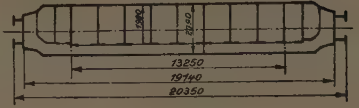
ABC4ü

18.



BC4ü

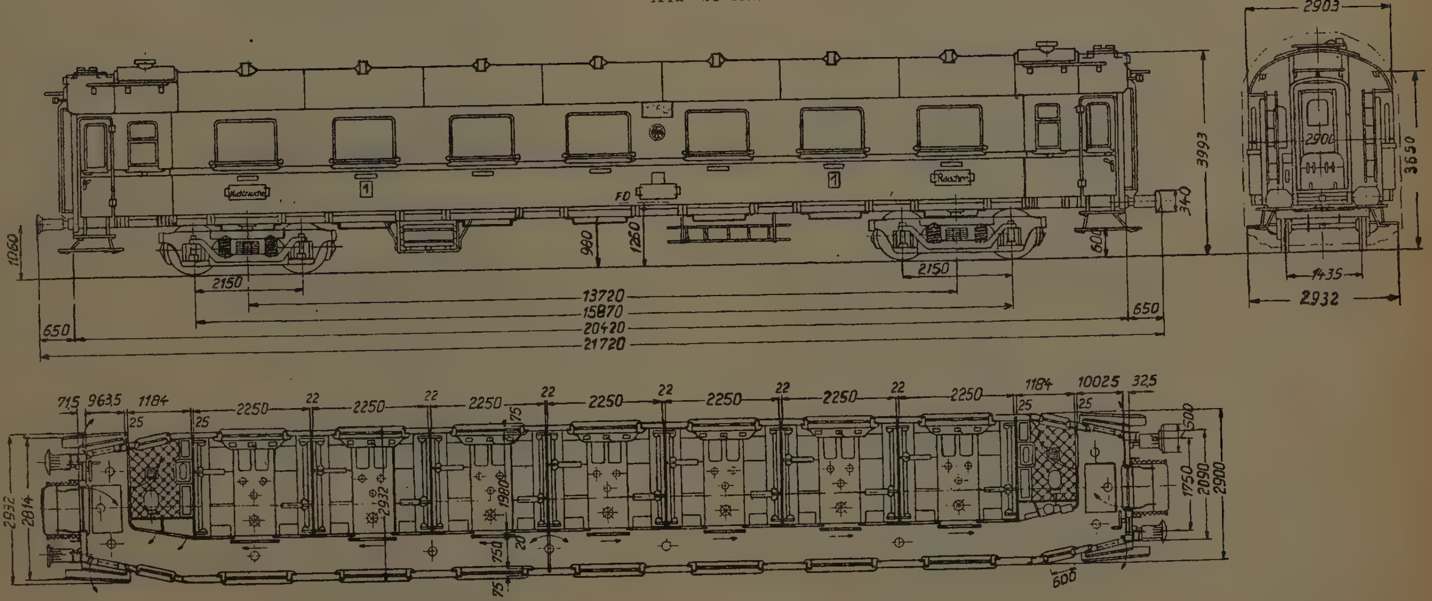
19.



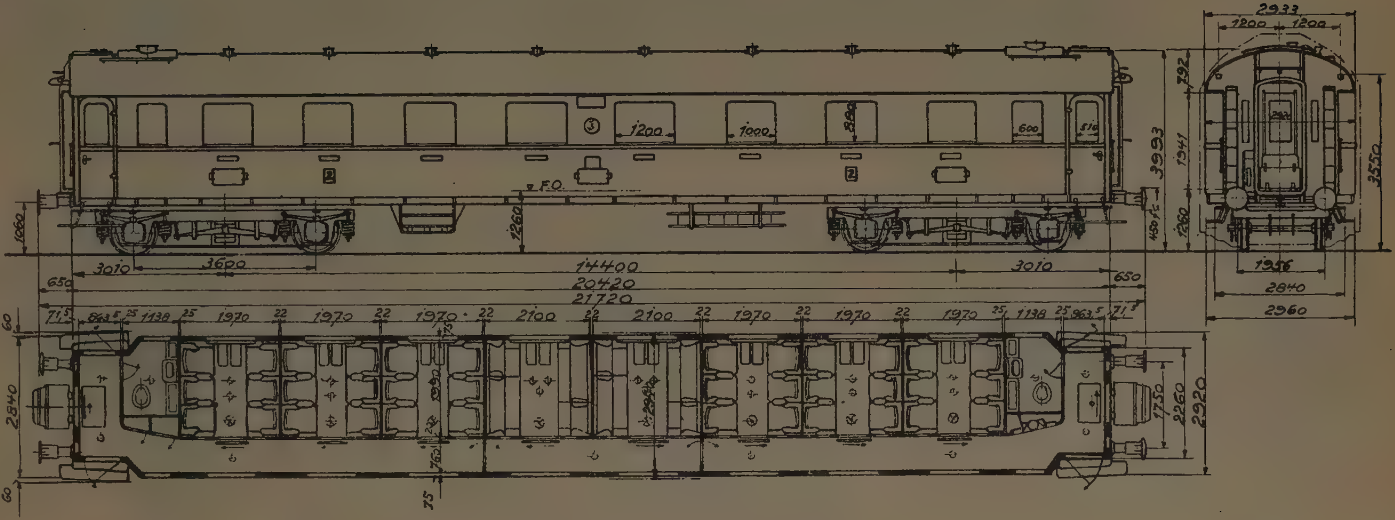
C4ü

APPENDIX III.

A4ü—26 coach.

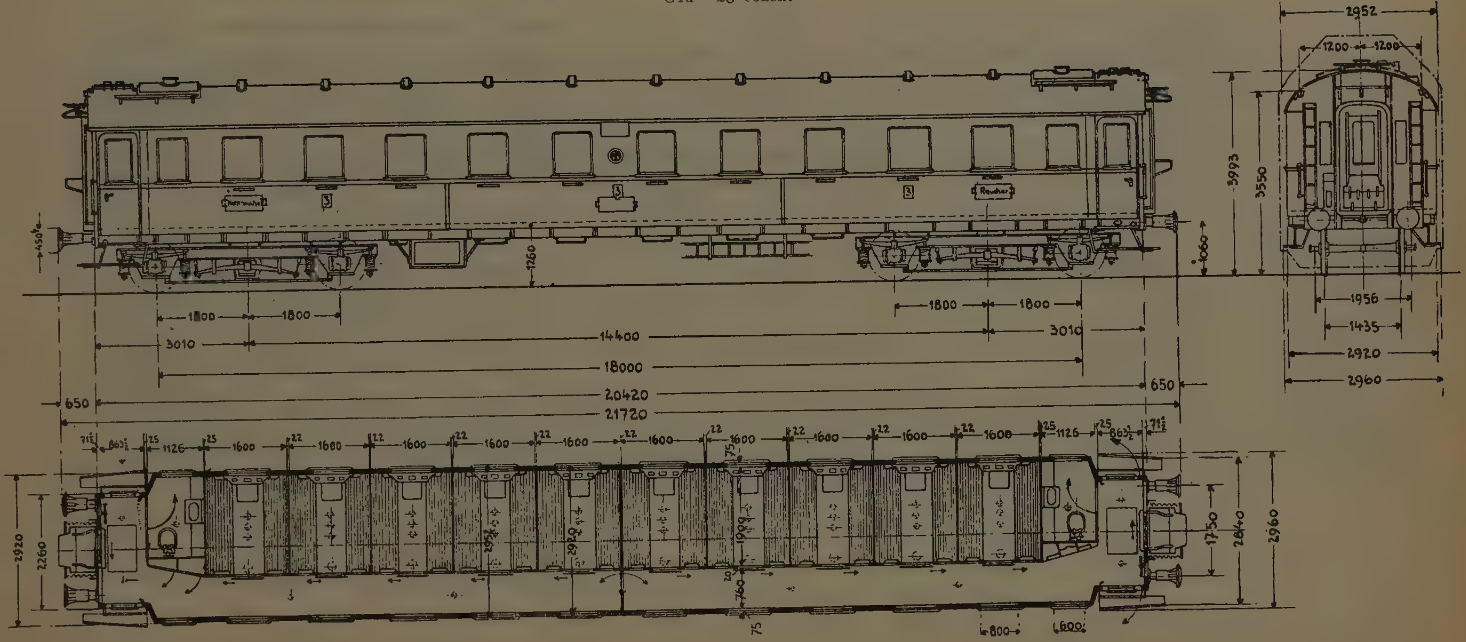


AB4ü—28 coach.



APPENDIX V.

C4ü — 28 coach.



[621 .33]

REPORT No. 2

(All countries except Europe)

ON THE QUESTION OF THE ELECTRIFICATION OF SECONDARY LINES (SUBJECT XIX FOR DISCUSSION AT THE ELEVENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION) (1).

By D. Eugenio RIVERA,
Inspector General of the Bridges and Roads Service of Spain,
General Manager of the Tangiers-Fez Railway,

and José Maria GARCIA-LOMAS,
Engineer of the Bridges and Roads Service,
Engineer attached to Headquarters of the North of Spain Railway Company.

Figs. 1 to 16, pp. 673 to 678.

We have thought it best to begin our report by stating that the detailed list of questions appended to the report was sent, as usual, to all the interested members of the Association; forty-eight of the ninety-two Administrations consulted have replied, but only two of these have provided information which could be used in drawing up the present report. The report has therefore been supplemented by information collected from the technical press of the world, after approaching personally other Railway Companies who do not belong to the Association, and finally after consulting Experts on the matter.

We should like to take this opportunity of expressing our thanks to the Railway Administrations who have been good enough to send us replies, or who have kindly facilitated our enquiries.

I.

The subject stated in the title of this report, and which refers to countries other than those of Europe, presents in the first place, two difficulties.

The first consists in the impossibility of defining in a general manner the railways which ought to be placed in the category of « secondary ». The gauge employed cannot be used to fix this category because in both Asia and Africa, the traffic carried on narrow gauge lines is of such importance as to be much greater than the traffic of some great European lines. Likewise, the volume of the traffic cannot be made the basis of a radical distinction, in view of the fact that there are numerous lines with little total traffic, which ought to be considered as main lines since they constitute arteries of great national or international political importance, connecting distant centres or countries.

The secondary railway, in the widest meaning of the term, should not be confused either with the railway of local interest, despite the fact that the two have features in common. The latter, the principal feature of which is its flexibility enabling it to reach a scattered number of small consumers, may, however, come within the category of secondary lines when it forms the tributary for lines of considerable traffic.

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(1) Translated from the French.

It has therefore been thought expedient to draw a distinction according to the features of the installation and working of the lines, as well as in the importance of the centres served, by adopting the definition appearing at the head of the questionnaire, which is as follows:

By « secondary railways » should be understood those of which the normal or narrow gauge lines, while forming part of the general system, connect less important centres, and of which the characteristic features of engine stock, general equipment, speeds and traffic are inferior to those of the main railways.

In the second place, both the secondary railways and those of local interest with their characteristic features of cheaper costs of installation and working are not very common outside Europe, with the exception of a few countries having a very dense population, such as Japan, for instance. In point of fact, these railways satisfy needs which might be called stable, in the poorer or more distant regions of the main lines, the possibility of the economic development of which is at present exhausted.

This is the least general feature possessed by railways, apart from the main lines, which are to be found outside Europe.

In the United States of America, for example, where the gauge is everywhere standard, the branches of the main lines are in general regarded as being part of them, subject to the same regulations, and possessing the same features as regards their working and equipment. In another group may be classed the suburban railways and the tramways of the large towns, as well as their extensions to nearlying centres, all the lines of which possess a considerable passenger traffic. Among these two groups, the interurban railways of the secondary type (*light railways*) or the tributaries of other main lines are less numerous and sometimes unstable in character; if they are laid down to satisfy progressively increasing needs, they obtain in a short time a considerable traffic, the demands of which finally transform the primitive character of the railway; on the other hand, the little used lines often disappear, absorbed by the very considerable and ever-growing road traffic.

Something of a similar nature to that which has just been discussed as regards the main line branches takes place in Canada, in the Union of South Africa and in Australia.

In the railways of the other countries having smaller economic resources, as well as in the colonial railways or those having a colonial character, which comprise the greater part of the total length of the remaining railways, the lines which may be regarded as being of secondary importance are also in the minority, if we except the pioneer lines which are often of a provisional character. Although most of them are laid with narrow gauge track (gauge of 1 metre [3 ft. 3 3/8 in.] or thereabouts) the original colonial lines and their extensions often quickly develop traffic and as a consequence equipment and engine stock equalling — if not surpassing — those of the main lines of the mother country.

On the other hand, reverting to the subject proposed, the economic question of electrification presents itself at once.

Outside the United States of America, where there are exceptional resources for the electrification of the railways, owing to both the enormous economic power of the country and the development of its generating plant and its distribution, the electrification of the railways, whether main or secondary, is restricted to isolated cases of a special character.

It must be admitted that the complete electrification of a line including the current collecting system, the substations the engine stock and finally feeder lines, still constitutes in most countries, an enormous economic problem for many of the main lines, and with a few exceptions a prohibitive luxury for those secondary railways which have been operated with steam traction from the beginning.

If the railways are standard gauge, and form an integral part of a main system, worked either entirely or in part with steam traction, the old rolling stock from the main lines is often utilised more or less economically.

In other cases these railways are operated (often because of the need of maintaining a public service which cannot be abandonned) on the basis of economic principles that rarely permit the complete transformation of the traction system to be considered, unless it is possible to obtain, in the case of private companies, a subsidy from the public authorities(1), for experience has proved in a series of examples, that the cost of constructing and equiping an economic line which has to exist on its own resources, is frequently greater than its earning capacity.

As regards colonial railways of a secondary character, these remain, as already mentioned, in general restricted to pioneer lines or to lines which tap certain regions of considerable agricultural wealth. It is certain that the exploitation of new regions depends essentially upon the means of transport, the installation and operation of which are necessarily subject to economic principles; in spite of this, however, the capital expenditure and even the working costs would be so high as to prevent often the normal development of the railway, even though the latter served regions of dense population. It is clear, therefore, that the question of electrification can only arise when the resources of the country are exceptionally suitable or when the difficulties offered by steam traction are insurmountable; in the other case, the colonial secondary railways, as well as those of the mother country, will be restricted in general to effecting the traction on their lines by more economical means than by the use of steam locomotives.

II.

The arguments set forth above will explain perhaps the lack of information to be obtained on the subject outside Europe, with the exception of the United States of America and Japan; they will be found to be sufficiently justified, moreover, on reviewing rapidly what has taken place in the various countries mentioned below.

Asia.

Japan. — From the railway point of view, Japan is one of the most interesting countries; both its main lines and its secondary lines have been developped to a considerable extent, and as regards the latter, this country forms, with the United States of America, the two nations outside Europe where electrification has been most widely extended.

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(1) In Italy and France, the State grants subsidies for the electrification of private secondary lines. Similarly, in Japan and Canada, there are laws granting subsidies to privately-operated secondary railways; the Japanese laws lay down the conditions to be observed in electrifying the said lines.

The reasons which have led to this fact are to be sought in the over-population of the country and in the great hydro-electrical resources which are to be found there; the latter amount to 6 500 000 H. P. for the whole year and 14 000 000 H. P. for six months in the year.

Altogether, the railway system represents about 21 000 km. (13 049 miles) of which 13 000 (8 078 miles) are operated by the State and 8 000 (4 971 miles) by private companies, the extent of the lines increasing annually by 400 km. (248.5 miles).

The private companies of secondary or local character number about 200 with 5 000 km. (3 105 miles) of lines (not counting the tramways) which in general serve as feeders for the State railways. Of the 5 000 km. mentioned above, 1 000 (621 miles) are electrified and 500 (310.5 miles) are operated with mixed traction (steam and electricity). Altogether the secondary railways possess 767 steam locomotives, 132 electric locomotives and 948 electric motor coaches. In addition, there are one locomotive and 88 passenger coaches fitted with petrol motors.

The standard gauge of the main lines is 1.067 m. (3 ft. 6 in.) This gauge has been adopted by most of the secondary railways, which gives the greatest advantages in the direct running between the two kinds of lines; there are also some other lines of 1.44 m. (4 ft. 8 1/2 in.) and of 0.76 m. (2 ft. 6 in.), the last gauge having been adopted for preference on lines of local interest and on tramways.

The State does not operate the secondary lines; it grants concessions to private companies, with or without subsidy according to circumstances, and a new concession is required when it is a question of electrification.

On some lines, electrification has been in operation ever since their construction (electric suburban trains and tramways have been running in Japan for the last 35 years); on other lines, for the most part, the traction system has been converted subsequently for economic reasons and there still exists a number of lines, the electrification of which has been proposed. It should be pointed out that the secondary railways are exposed to a very great and daily increasing competition from road transport; for this reason many companies have been compelled to resort to the electrification of their lines, so as to increase the number of the trains and their speed, by adapting their weight to the requirements of the service, and operating the latter under the best economic conditions, specially as regards the cost of power and repairs to the engine stock.

On the secondary railways, the average traffic is 800 passengers and 150 t. of goods daily and per kilometre (241 Engl. tons per mile) of line.

As regards passengers, the traffic is 310 per kilometre (499 per mile) per day on railways operated with steam traction, and 1 860 per km. (2 993 per mile) per day on electric railways, the last figure giving an idea of the important development of the passenger traffic.

On the electric railways, the passenger trains consist of a single motor coach, or of a motor coach with two or four trailer coaches according to the circumstances. With steam traction, the composition of the trains is one locomotive and two or four coaches. The number of daily trains varies considerably; for the secondary railways the average is 12 to 70 (on the suburban electric railways, this figure varies between 250 and 1 000).

Goods transport is generally done by trains composed of one electric locomotive and two or three wagons, or a steam locomotive and three to six wagons. Goods trains, where such exist, are made up of three to twenty wagons, and their number varies from 4 to 10 per day; the maximum loads pulled are 550 tons with electric traction, and 700 tons on an average with steam locomotives.

Whatever be the system of traction, the staff of a train consists of a driver and a guard; for long goods trains two guards and one or two brakesmen are carried, if the train is not equipped with the continuous brake.

As regards the track conditions, the rail employed the most by the secondary railways of 1.067-m. (3 ft.-6 in.) gauge is one of 30 kgr. per m. (60.5 lb. per yard), which enables vehicles belonging to the State Railways to run on these railways; on certain lines where the trains run at greater speeds, a rail of 50 kgr. per m. (100.8 lb. per yard) is selected. On the 2 ft.-6 in. gauge lines, the weight of the rails varies from 9 to 20 kgr. per m. (18.1 to 40.3 lb. per yard). All the rails employed are of the « Vignoles » type on sleepers; the maximum allowable loads are 13 tons for the 3 ft.-6 in. gauge lines, and 7 tons for the 2 ft.-6 in. gauge lines.

The provisions of the law relating to the secondary railways limit the gradients to 1 in 30; however, in view of certain local circumstances, the use of steeper gradients is allowed, and these attain 1 in 12.5 on some electric railways.

At the present time, the steam traction is effected on secondary lines, as already stated, by 767 locomotives; of these 226 correspond to the 2 ft.-6 in. gauge track, and weigh 5 to 18 t. (4.9 to 17.7 Engl. tons), 520 correspond to the 3 ft.-6 in. gauge track, with a weight of 14 to 60 t. (13.8 to 59 Engl. tons) and 24 locomotives are employed on the 4 ft.-8 1/2 in. gauge. The majority of these locomotives are fitted with hand and steam brakes; the more modern are provided with compressed air brakes. The average daily run of these locomotives does not exceed 80 km. (50 miles). The average purchase price is £80 per ton, and the average annual expenses which it has been possible to obtain amount to £401-10sh. per locomotive for the coal consumed, and £14-19sh. for lubrication.

As regards electric traction, the system employed is that of high tension direct current (1 200 to 1 500 volts) or low tension (600 volts); the alternating current, supplied in general by power companies (in very rare cases the railway produces its own power) is transformed in sub-stations belonging to the railway. The equipment of the original sub-stations mainly consisted of motor generator sets; later rotary convertors were used, and to-day mercury vapour rectifiers are being installed; the use of automatic appliances is likewise extending.

The price of the kilowatt-hour provided varies in different localities from 0.5 to 1 penny, a minimum compulsory consumption being generally stipulated.

The overhead lines are of the direct suspension type on some railways, but most of them utilise single catenary suspension, with a support-cable, usually of bronze or copper, which serves as a feeder. As a result of the development of the catenary system of suspension, the use of pantographs is also general.

The rail joints are generally bonded whether the ends of the rails are welded or fishplated.

Of the electric locomotives in service, 25 weighing 6 to 11 t. (5.9 to 10.8 Engl. tons), correspond to the 2 ft.-6 in. gauge lines; 104 weighing 18 to 50 t. (17.7 to 49.2 Engl. tons) are in service on the 3 ft.-6 in. gauge lines, and three on those of 4 ft.-8 1/2 in. gauge. Their power varies from 60 to 1 000 H. P., generally distributed among four motors mounted on two bogies (some of the smaller locomotives have only two motors); compressed air, electric, and hand-braking is employed. Automatic couplings are widely used, as well as multiple unit control. Sixty per cent of these locomotives have been built in Japan.

The cost of electrification varies greatly according to the equipment of the line. The sub-stations cost from £5 to £15 per kilowatt installed, the contact line from £300 to £1 800 per kilometre (£483 to £2 897 per mile) of single or double track, the locomotives from £130 to £240 per ton and the motor coaches about £100 per ton (approximately £7.5 per H. P.).

As regards the petrol motor vehicles employed by some railways, their capacity for 3 ft.-6 in. gauge lines is 20 passengers seated and 20 standing; for the 2 ft.-6 in. gauge lines these numbers are reduced to 15. The average daily run of these coaches is 120 km. (75 miles); the maintenance and repair expenses are 7 d. per day, the running expenses are 3 sh. per day and the cost of lubrication is 0.36 d. per km. (0.58 d. per mile).

In addition to a portion of the secondary railway system, some of the State railways have been electrified; such are the Isni-Toge rack railway, electrified since 1910 with 3rd rail, 650 volts, D. C.; the girdle and suburban lines of Tokio (the motor trains of which leave the main station of Tokio), originally constructed for 600 volts, and converted to 1 200 volts, D. C. in 1923, and the Tokyo-Yokohama-Sakuragicho, 1 200 volts D. C., which is used specially for passenger traffic between the capital and the important city of Yokohama.

The programme of electrification also included the lines Tokio to Kobe (608 km. = 378 miles) and Chuo d'Idama to Kofu (130 km. = 80.8 miles) which were to have been equipped for 1 500 volts, D. C., but owing to the earthquake of 1923 which upset the financial position of the country, the programme has been reduced for the moment to the electrification, now completed, of three sections of the first-mentioned of these lines (totalling 72 km. = 44.7 miles).

The Colonial Railways of Japan.

a) *Chosen (Korea).* — The main railway system, of about 2 100 km. (1 305 miles) belongs to the State and connects with the South Manchuria Railway. Under protection of the act of 1912, favouring the construction of secondary railways in Korea, a system of privately-owned railways was created, the length of which at present attains 3 000 km. (1 864 miles). These railways, of 3 ft.-6 in. gauge are run by steam traction, with the exception of the Kongozan Electric Railway, electrified when it was built, which will have a length of 116 km. (72 miles) leaving the station of Tetsugen, on the Seoul-Genzan line of the State railways, for Diamond

Mountain. At the present time, traffic is open between Tetsugen and Shodo over a distance of 68 km. (42.3 miles).

The factors which decided electrification were the facilities of being able to procure hydro-electric power at a price lower than that of oil or coal. The capacity of the central hydro-electric power station is 10 850 kw., the power being transmitted to the two sub-stations at present in existence by three-phase lines at 66 000 volts; each of the sub-stations is equipped with a transformer plant and two motor-generator sets of 500 kw., the annual power consumption amounting to 260 000 kw.-h.

The contact line, on the single catenary suspension system, is fed with direct current at 1 500 volts, following the standard system adopted by the Japanese State Railways.

The motor stock consists of 6 motor coaches, weighing 44 t. (43.3 Engl. tons) and having a total power of 280 H. P. distributed over 4 motors connected in pairs in series. The control is of the multiple unit type, the coaches being equipped with automatic couplings and heating appliances. The bodies are built of wood, and their capacity is 72 places.

The ordinary traffic is assured by passenger trains and mixed passenger and goods trains; the former comprise a motor coach and the latter a motor coach and two wagons. The motor coaches run a distance of 162 000 km. (100 660 miles) annually, and the distance run between two consecutive inspections and liftings is 80 000 to 110 000 km. (49 700 to 68 350 miles) (2 to 3 years).

b) *Formosa.* — In Taiwan, the State Railways have an approximate length of 1 000 km. (621 miles). The privately-owned railways have been built chiefly for the transport of sugar; with the exception of two lines of 3 ft.-6 in. gauge, the others are 2 ft.-6 in. gauge lines and represent a total length of 2 100 km. (1 305 miles), of which 500 km. (310 miles) are intended for the public service. All the railways are operated by steam.

Manchuria (China). — The main system is that of the South Manchuria Railway, of considerable political importance, and of which the operation is at present governed by the Chosen Government Railways of Korea (Japan). Its length is 1 120 km. (696 miles); it is standard gauge (1.435 m. = 4 ft. 8 1/2 in.). Since 1914, the section Fushun-Colliery (40 km. = 25 miles) has been electrified with direct current at 1 200 volts.

The other Manchurian lines, Peking-Mukden (Chinese State Railways), the Changhun-Kirin Railways, the Supinghai-Taonan Railways, etc., and their branches are all of standard gauge and have not the character of secondary railways.

In the remaining portion of the Chinese Empire, there exists a veritable chaos of railways built by firms of all countries, but in view of the situation in this country it has not been possible to obtain any information.

It appears, however, that in Shanghaï it is intended to electrify shortly the suburban railways of that town.

Siam. — Initial electrification installations have been made in this country on the main railways, which have been recently standardised to the gauge of 1 m. (3 ft. 3 3/8 in.).

The Tramways and Electricity Company of Bangkok has completed the electrification of the Paknam Railway, the supply line of which is fed by a steam power station of 5 000 H. P.

Indo-China. — The main railway system consists of 2 300 km. (1 429 miles) of 1 m. (3 ft. 3 3/8 in.) gauge operated by the Government of the Colony. The secondary or local lines include 200 km. (124 miles) of 1 m. (3 ft. 3 3/8 in.) and 0.60 m. (1 ft. 11 5/8 in.) gauges amongst these being the Hanoï Tramways and suburban lines electrically operated.

The whole of the other railways both main and secondary are steam operated.

India. — This country possesses 64 000 km. (39 768 miles) of railways, of which 56 000 km. (34 797 miles) may be regarded as main lines, with a gauge of 5 ft.-6 in. and 3 ft.-6 in. The railways of a secondary character are of very different gauges, varying from 3 ft. 6 in. to 2 feet, on many lines of agricultural or local importance.

The railway system is still in a state of active development; about 1 000 km. (621 miles) of lines are constructed annually, most of which are connections with the main lines. The traffic on these lines is very important, although they are narrow gauge, which involves the use of special locomotives to haul the necessary loads. For instance, on the 1-m. (3 ft. 3 3/8 in.) gauge lines of the Madras and Southern Mahratta Railway and the Burma Railway, steam locomotives of the *Garratt* 2-8-0 + 0-8-2 type are employed.

Only the main lines of the Great Indian Peninsula Railway and the Bombay, Baroda and Central India Railway, however, have been electrified. The first has electrified its suburban lines of Bombay-Kalyan (71 km. = 44.1 miles, and those of Bombay-Kalyan to Igatpuri and Poona (480 km. = 298 miles) are in a very advanced stage of electrification, all of them having a very important passenger and goods traffic.

As regards the second of the railways mentioned above, electrification of the Borivilli-Bombay-Colaba line (37 km. = 23 miles) was completed quite recently. There is an enormous passenger traffic on this line, attaining the annual figure of 45 millions. At the present time, the service is assured by 160 electric motor coaches. with trains of up to 8 units (motor coach and trailers).

These two railways have a gauge of 5 ft.-6 in. and are operated on direct current at 1 500 volts, officially adopted in England and her colonies.

This voltage will also be employed for the electrification, shortly to take place, of the Madras suburban railways belonging to the South Indian Railway.

The railways of lesser importance, as well as the lines of local interest, are steam operated, and confine themselves to improving the locomotive stock, if required by the increase in traffic, or to adapting this material for the purpose of effecting a saving on certain special traffic, especially the passenger traffic.

The Kalka-Simla line, for example, with a 2 ft.-6 in. gauge, employs locomotives of the Kitson-Meyer 2-6-2 + 2-6-2 type for the goods traffic; for the passenger traffic, this railway has sucessfully employed, for some time now, petrol motor coaches.

The South Indian Railway also utilises this type of coach on various metre gauge lines with a light passenger traffic.

The Ceylon Government Railways possesses a system with 5 ft.-6 in. and 2 ft.-6 in. gauge tracks, operated entirely by steam; quite recently, *Garratt* 2-6-2 + 2-6-2 locomotives have been put into service for the goods traffic, on 5 ft.-6 in. gauge lines, and for the passenger traffic, Sentinel-Cammel and Clayton steam motor coaches have been used on a large scale since 1925 on lines of both gauges, and Sentinel-Cammel articulated units have been used on the 5 ft.-6 in. gauge lines. The motor coaches, built in England, a country which has specialised in this type of vehicle, are extremely interesting, and have helped to effect a considerable saving in the traction costs, which explains the increasing numbers in use.

The new single Clayton type units have a capacity of 8 first class passengers and 60 third class; they are fitted with automatic vacuum brake, hand brake and electric lighting. The engine, with two high pressure cylinders, is mounted horizontally between the axles of the engine bogie, and engages the front axle of the said bogie through gears; the power is transmitted to the other axle of the bogie by a horizontal connecting rod. The boiler is of the vertical type, and is fitted with a feed-water heater. The coach may be driven from either end; the water tank and coal supply ensure a run of 200 km.

The Sentinel-Cammel articulated units have an engine on the middle bogie, and provide 130 places, 16 first class and the remainder third class. The brake is the automatic vacuum brake and the lighting is electric. The engine has two high pressure cylinders and drives the two bogie axles through a chain drive.

The use of these units enables the competition of the motor omnibuses to be met; it is interesting to note, however, that the Ceylon Government Railways have decided to run a line of road motor coaches as a trial to serve as a feeder to the railway in a rich region in active development.

Malacca. — The Federal States of Malacca have a railway system of 1 650 km. (1 025 miles) with 3 ft.-6 in. tracks entirely steam operated; tractors of a special type are used for operating lines of smaller gauge.

The Singapore municipality has a num-

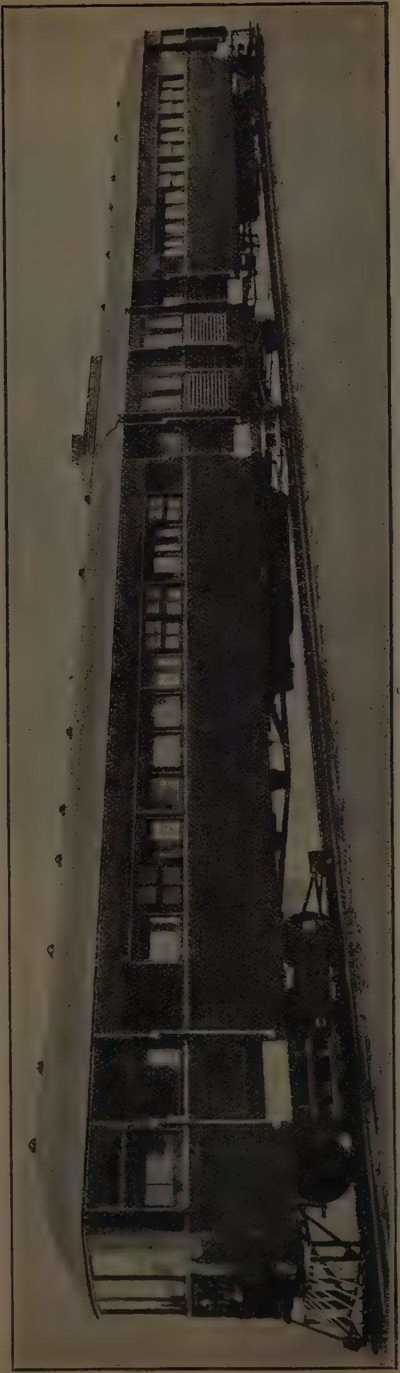

Fig. 1. — Articulated steam motor coach of the Ceylon Government Railways.

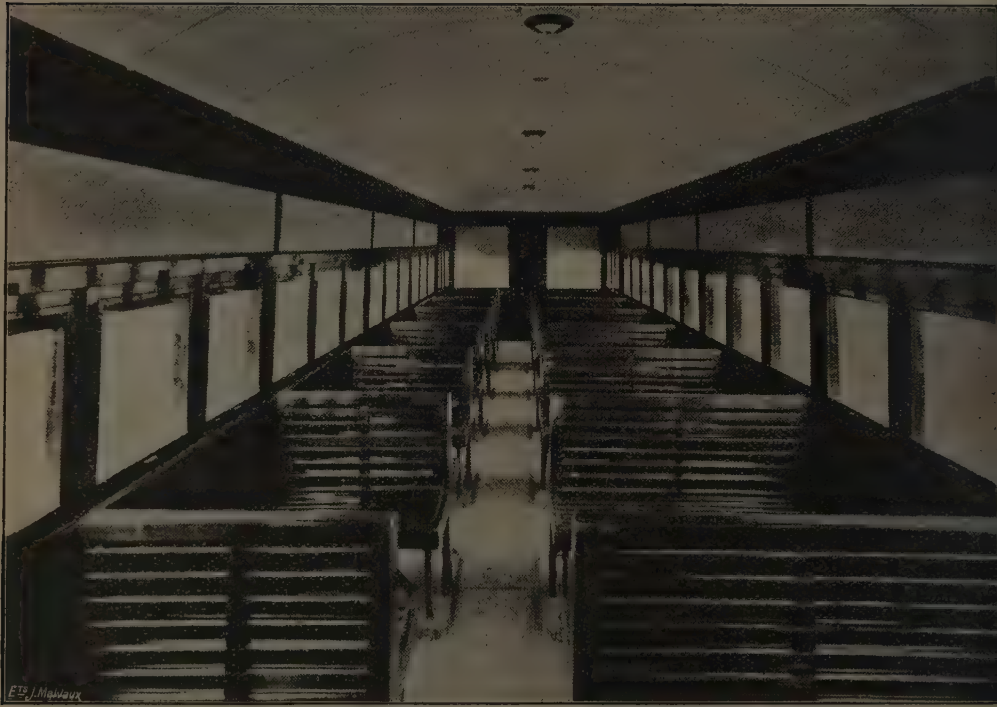

Fig. 2. — Interior of the 3rd class compartment of the articulated motor coach of the Ceylon Government Railways.

ber of Atkinson-Walker steam tractors, with two axles, in service on lines of 2-foot and 3-foot gauge.

Dutch East Indies. — These Dutch colonies, the most important of which are New Guinea, and the islands of Sumatra, Borneo, Celebes and Java, possess a total railway system of about 6 000 km. (3 728 miles), most of which are 3 ft.-6 in. gauge, adopted as standard, as in other colonial countries, following the example of the Cape Colony in Africa, where this gauge was originally used.

On these narrow gauge lines, both State-owned and privately-owned, and which to-day constitute the main lines, the traffic has grown so considerably that problems very difficult of solution have arisen, and which are still further complicated as a result of the excessively difficult nature of the lines and the generally very unfavourable climatic conditions.

The island of Sumatra has four railways; that of the North belonging to the State, as does that of the West; that of the South, which serves the capital, and the Deli Railway, belonging to a private company.

The first of the above-mentioned railways has a gauge of 0.75 m. (2 ft. 5 1/2 in.) and the others one of 1.065 m. (3 ft. 5 15/16 in); it should be mentioned that very steep gradients occur on the West Railway, attaining in many places 1 in 12.5. Steam is used on all the railways; traction is mixed — rack and adhesion — on the West Railway, but electrifciation has not been considered on any of the railways.

In the island of Java, which has 35 million inhabitants, (the density of the population is greater than that of Belgium) the railways are in a very highly developed state from the technical point of view. Notwithstanding the narrow gauge, the trains run at speeds of 100 km. (62 miles) per hour; *Mallet* locomotives and locomotives with tenders are employed, weighing 140 tons in working order, and hauling trains of 1 000 to 1 200 tons, reduced to 600 tons on mountain lines with a gradient of 1 in 58.

The State Railway comprises 2 900 km. (1 802 miles) of standard lines; there are also a considerable number of secondary lines of 0.60 m. (1 ft. 11 5/8 in.) gauge.

The main lines and the secondary lines are generally operated by steam; the electrification programme only covers a distance of 120 km. (75 miles) of single track line on the State main lines, the sections Tandjong-Priok-Meester Comelis (50 km. = 31 miles) and Manggarai-Buitenzorg (45 km. = 28 miles) being already completed. The system employed for the electrification is that of direct current at 1 500 volts, officially adopted in Holland. The construction of hydraulic stations was begun first, with the 70 000 volts transmission lines, which feed transformer sub-stations, equipped with motor-generator sets and mercury vapour rectifiers.

The reason for this electrification has been the increase in traffic (on the first section to be electrified, 200 trains are run daily, with motor coach and trailer units of 500 H. P.), and the abundance of water power possessed by this island, but which on the other hand is lacking in coal; this enables one to expect that, in time, the railway system will be electrified altogether.

Africa.

For its 38 millions of km² (14 672 000 sq. miles) of area, Africa possesses 63 000 km. (39 147 miles) of railways, distributed, like its population, very unevenly.

Of all these railways, 20 500 km. (12 738 miles) belong to the Union of South Africa, which in importance is followed by Algeria (4 700 km. = 2 920 miles), Egypt (4 700 km.) = 2 920 miles), French West Africa (3 500 km. = 2 175 km. miles), the Belgian Congo (3 200 km. = 1 988 miles), the Anglo-Egyptian Sudan (2 800 km. = 1 740 miles), Nigeria (2 600 = 1 616 miles), Morocco (2 400 km. = 1 491 miles), Tunisia (2 100 km. = 1 305 miles), Kenya and Uganda (1 850 km. = 1 150 miles), Tanganyika (1 800 km. = 1 118 miles), Angola (1 650 km. = 1 025 miles), French Central Africa (1 100 km. = 684 miles), Mozambique (1 050 km. = 653 miles), the Gold Coast (850 km. = 528 miles), Abyssinia (800 km. = 497 miles), Madagascar (700 km. = 435 miles), etc.

All gauges are represented, and generally there are several gauges in each country, although one may predominate on the main lines.

The standard gauge of 1.435 m. (4 ft.-8 1/2 in.) is found principally in Egypt and French North Africa, but it only forms 11 % of the whole. The narrow gauges are 1.067 m. (3 ft. 6 in.) (Union of South Africa, Algeria, Rhodesia, Belgian Congo, Angola, Sudan, Nigeria); 1 m. (3 ft. 3 3/8 in.) (French West Africa, Kenya and Uganda, Tanganyika, Tunisia, French Central Africa, Algeria, Angola, etc.); 0.76 m. (2 ft. 6 in.) (Egypt, Belgian Congo, Nigeria) and 0.61 or 0.60 m. (2 feet or 1 ft. 11 5/8 in.) (Union of South Africa, Egypt, Morocco, Belgian Congo). The gauge of one metre or nearly one metre preponderates with about 49 000 km. (30 450 miles) of lines.

Only a small proportion of the total length stated above corresponds to lines which may be classed among those of a secondary character, with the exception of pioneer lines and agricultural railways, the gauge of which is for the most part 0.60 m. (1 ft. 11 5/8 in.).

Union of South-Africa. — With the exception of the 660 km. (410 miles) of privately owned lines, all the railways belong to the State (Union of South Africa Government Railways) being operated conjointly with the other forms of transport and the ports by the Ministry of Railways and Harbours, which in a short time have acquired a surprising prosperity.

The gauge is normally 3 ft. 6 in. There are 18 870 km. (11 725 miles) of lines with this gauge, on which steam and electric engine stock of the heaviest type is used, and 1 630 km. (1 013 miles) of 2-foot gauge lines.

The secondary lines and branch lines of these two gauges are generally operated by steam; petrol motor coaches are employed on some of them for light passenger traffic, but it has not yet ben considered necessary to proceed to electrification; on the other hand, the conditions are not very favourable for electrification, the country not being very rich in water power.

Electrification has only been carried out on the Durban-Pietermaritzburg and Glencoe to Natal line, and on the suburban lines of Capetown.

On the first of these lines, electric service has been organised on the section Pietermaritzburg-Glencoe (282 km. = 175 miles); it is being continued towards Durban (113 km=70 miles). The object of this electrification is to meet the enormous traffic amounting to 15 000 tons daily in the direction Glencoe-Pietermaritzburg, which steam traction is not able to cope with.

The system employed is that of direct current at 3 000 volts; the contact line is fed from 12 automatic sub-stations, equipped with motor-generator sets obtaining their power from a steam power station of 60 000 kw. capacity. The electric locomotives, consisting of units of 1 200 H. P., B+B type, which may be coupled in multiple units, adapt themselves to any load and any traffic. They may be employed for 20 hours daily, and their monthly run is 11 000 km. (6 835 miles) compared with the 12 hours' service of steam locomotives making monthly runs of 4 000 km. (2 486 miles). Moreover, the number of units under repair is 6 %, as against the 21 % of steam locomotives. The 78 units originally put into service repaired 115 heavy steam locomotives.

The electrification of the Capetown suburban railways was justified by the considerable passenger traffic, which on the line Capetown-Simonstown (37 km. = 23 miles) exceeds 20 millions annually.

Electrification has been extended besides to two other less-important branches, which, together with the abovementioned line, brings the total length electrified to 46 km. (28·6 miles); the direct current system at 1 500 volts has been adopted. The contact line is fed by six automatic sub-stations at distances apart of 6 to 10 km. (3.7 to 6.2 miles) equipped with rotary convertors, receiving energy from a 30 000 kw.-steam power station.

The service is assured by motor coaches and trailers, electrification being restricted for the moment to passenger traffic. The goods service, which is not so important, is worked by steam locomotives.

Algeria. — This French colony has 4 700 km. (2 920 miles) of railway, of which 2 500 km. (1 554 miles) are of standard gauge, 1 500 km. (932 miles) of 3 ft. -6 in. gauge, 630 km. (391 miles) of metre-gauge and 60 km. (37.3 miles) of 2-foot.

The main lines (the State Railways and the lines of the French Paris-Lyons-Mediterranean Company run parallel to the coast, with branches towards the ports and the other important centres. There are also three main penetration lines of metre-gauge, and other small lines of various gauges. The « Société des Chemins de fer sur Routes d'Algérie » operates a system of 225 km. (140 miles) of railways of local interest, having a gauge of 3 ft. 6 in. and 22.5 km. (14 miles) of urban and suburban tramways serving the town of Algiers.

All the above-mentioned lines are steam operated with the exception of the tramways, which are electric; they possess 60 motor coaches of 5 to 8 tons, and 70 trailer coaches of 3, 5 and 6 tons. The trains of motor coaches and trailer

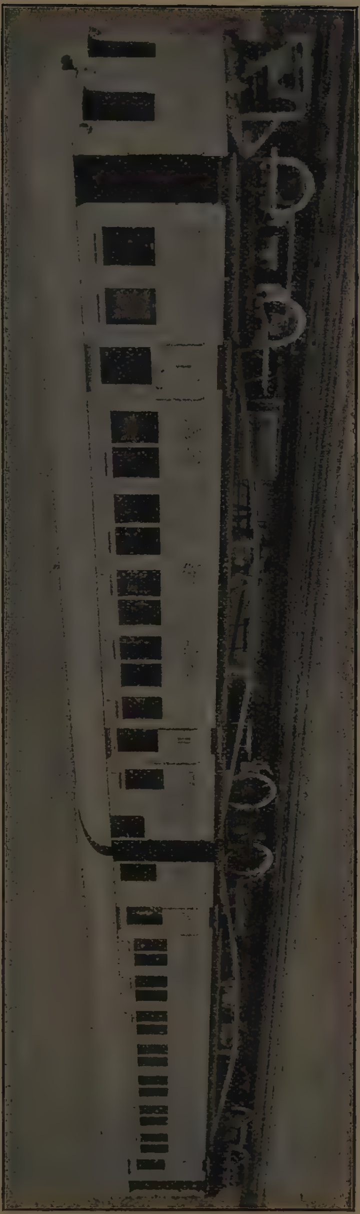

Fig. 3. — Articulated steam motor coach of the Egyptian State Railways.

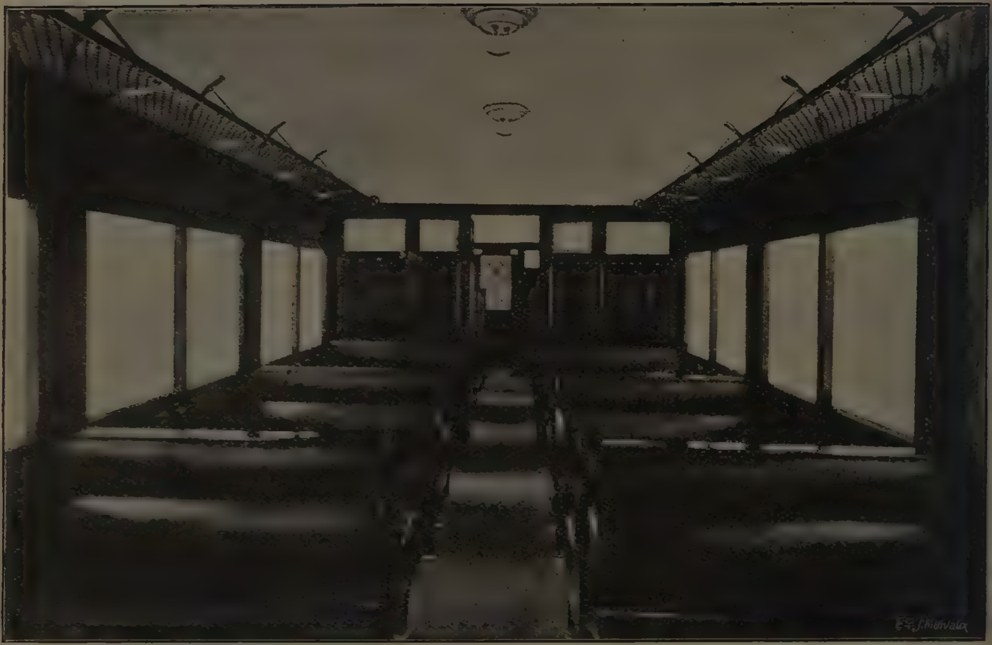

Fig. 4. — Interior of the 1st class compartment of the articulated motor coach of the Egyptian State Railways.

coaches have about 100 seats, their annual mileage being 2 200 000 motor coach-km. 1 367 000 miles) and 3 100 000 trailer coach-km. (1 926 300 miles) for a traffic of 25 million passengers; the power consumption is 48 w.-h. per tonne-kilometre (78.4 watt-hours per Engl. ton-mile).

Egypt. — The State Railways comprise the main lines leaving Cairo for Alexandria, Port-Said, Ismailia and Suez, plus a series of connecting or branch lines of the above in the region north of Cairo, about a total of 3 400 km. (2 113 miles) of standard gauge lines (4 ft 8 1/2 in.) to which should be added the 200 km. (124 miles) of the line (2 ft.-2 3/8-inch gauge) penetrating as far as the Kharga Oasis.

The operation of this system, as regards both the main lines and those of lesser importance, is effected by steam, the electrification of the section Cairo-Heluan alone being projected. The 32 km. (20 miles) of this section are congested with traffic.

Although there can be no question of electrification on a general scale, in view of the scanty hydro-electric resources of the country, efforts are being made to economise in the steam traction at present in use by introducing the use of tractors specially adapted for short distance passenger traffic. The most modern stock consists of articulated steam motor coach units, of the Clayton type with a seating capacity of 107 places, 17 first class, 20 second class and 70 third class; the middle bogie carries a Clayton horizontal steam engine, engaging one of the driving axles through gear, the power being transmitted to the other axle by connecting rod. The vertical boiler is situated at the end of the coach on the engine bogie; the water tank and coal supply are located on the adjacent end of the second coach.

The coaches are lit by electricity, and the saving effected in the cost of traction is considerable; each complete unit weighs 45 t.

There is, in addition, in Egypt, an important system of light railways of 2 ft.-6 in. gauge, mainly run for agricultural purposes by the Egyptian Light Delta Railways Ltd., having a total length of about 1 000 km. (621 miles); the goods traffic is very considerable (about 600 000 tons net annually), and demands the use of locomotives with tenders of various types (2-6-2, 0-6-4, 4-4-0) and bogie wagons. In order to form light trains under the most economic conditions and especially for the passenger service (amounting to 9 millions annually), double axle Sentinel tractors are employed. These have given good results, and enable the competition of the motor omnibuses to be met. The coal consumed by these tractors is 2.207 kgr. per km. (7.83 lb. per mile) as against 5.523 kgr. per km. (19.59 lb. per mile) for the locomotives; their use thus results in a reduction of the total cost of a train-kilometre by 50 %.

French West-Africa. — The railway system of this possession comprisse 3 400 km. (2 113 miles) of metre-gauge lines; there are also other important lines at present being built. Altogether these lines carry a considerable traffic; on the Thiès-Niger Railway, for instance, during the period of maximum traffic, 26 trains are run daily, passenger and mixed and 50 goods trains.

Now that the section Thiès-Kayes has been connected with that of Kayes-Niger, the question arises of electrifying the last-mentioned railway by utilising the Jonina falls of the Senegal River (French Senegal). The ever-growing increase in the traffic justifies this conversion, as do also the steep gradients, which on the Kayes-Bamako section, reach 1 in 33, thus restricting to 140 tons the maximum load for trains using the most powerful steam locomotives, the weight of which cannot exceed 9 tons per axle on account of the nature of the track.

Belgian Congo. — This colony possesses a system of railways in full development, comprising already more than 3 000 km. (1 864 miles) of lines. A length almost as great as this is being planned or is being built, the main object being to provide easy outlets for the products of the Katanga mines. The commonest gauge is 3 ft. 6 in. and this gauge has been adopted for the very important lines of the Katanga and the Lower Congo. Other lines have been constructed with a 2 ft.-6 in. gauge, but have been subsequently widened, as is now being done on the Matadi (Congo River) to Kinshasa line, now in course of reconstruction, owing to the congestion of traffic which has already taken place. It has also been planned to electrify this line by the aid of the energy to be obtained from the projected Yusiki hydro-electric station on the Congo River.

In addition to these main lines, there

exist others of less importance, having a gauge of 2 feet, among which are the light railways of the Mayumbe and the Akete to Bondo line and branches, a total say of 220 km. (137 miles) operated by the « Compagnie des Chemins de fer Vicinaux du Congo »; this line was constructed with the intention of increasing its gauge later to 3 ft. 6 inches.

The service is operated entirely by steam, the use of motor coaches and trailer coaches for passenger traffic being frequent; an auxiliary company is also running road services as feeders of the above-mentioned system.

Rhodesia. — The railway system of Rhodesia altogether consists of 4 000 km. (2 486 miles) of lines serving five distinct areas, 3 000 (1 864 miles) of which are operated by the administration of the Beira, Mashonaland and Rhodesia Railways, and 1 000 (621 miles) by that of the South African Railways.

All the present system is 3 ft.-6 in. gauge, and has undergone a complete change so as to adapt it to the important traffic which is being developed, mainly for ore. The old 2-foot lines have been converted to this gauge; at the same time the gradients have been rectified, and the bridges and track have been strengthened, a rail of 30 kgr. per metre (60.5 lb. per yard) having been laid, with which it is intended to relay gradually all the lines.

The system is operated by steam by means of Garratt 120-ton locomotives of modern type, and bogie wagons for the transport of ore, 16 tons tare and 45 tons load. No lines of a purely secondary character are operated; on a few branch lines, petrol motor coaches are utilised for light passenger traffic.

Anglo-Egyptian Sudan. — The Sudan Government Railways (operated by the State) possess a system of 2 800 km. (1 740 miles) of 3 ft.-6 in. gauge, emploing modern steam locomotives, with which trains of up to 900 tons load are made up.

Recently, steam motor coaches have been put into service under economic conditions for light passenger trains on less important sections; the track is also being strengthened by laying rails of 37 kgr. per metre (74.6 lb. per mile) in place of the rails of 25 kgr. per metre (50.4 lb. per yard) which were generally employed in building the original lines.

In addition to the 4 000 km. (2 486 miles) of water transport routes, the State also runs motor road services in order to open new routes for the traffic (mainly in coal) where the railway cannot be extended as yet in an economic manner.

As for the rest, the country is in full development; a vast irrigation plan has been projected in the Jezira plain, the inauguration and improvement of the service by road and tramways at Kartum and Omdurman, together with important electrical installations.

Nigeria. — This country possesses a system of 2 380 km. (1 479 miles) of lines, of 3 ft.-6 in. gauge, and 220 km. (137 miles) of 2 ft.-6 in. gauge, constituting the Bauchi Light Railway, operating a traffic of ore and cotton.

There is an important traffic of coal, ore and cotton on the main system, which possesses various lines, formerly of narrow gauge. All the services are effected by steam; in addition, large areas of cotton plantations are served by road transport.

With the exception of the Bauchi Railway, already referred to, and which has a rail of 15 kgr. per metre (30.2 lb. per yard), all the branches have the same gauge, and are operated in the same way as the main lines.

The track originally laid on these lines with rails of 25 to 30 kgr. per metre (50.4 to 60.5 lb. per yard) is being relayed with rails of 40 kgr. per metre (80.6 lb. per yard) in order to allow of loads of 16 tons per axle. The rails which are removed are allotted to sections where the traffic is less heavy and to other projected lines.

Morocco. — In the French Protectorate of Morocco, the lines of communication are passing through a period of active development and comprise two sorts of transport : road transport, assured by a system of 3 400 km. (2 113 miles) of main roads and 1 700 km. (1 056 miles) of secondary roads, and rail transport, served by two systems, one of the normal gauge of 1.435-m. (4 ft. 8 1/2 in.), at present about 800 km. (497 miles) and another, the secondary railway, of 0.60 m. (1 ft.-11 5/8 in.) gauge, the length of which is about 1 500 km. (932 miles).

The first of these systems comprises the Franco-Spanish Tangiers-Fez Railway, the other railways are operated by the Morocco Railway Company, in which are interested the French Paris-Orleans and Paris-Lyon-Mediterranean Railway Companies. The system of narrow gauge secondary railway was originally constructed for military reasons, and is at present operated by an official company, the « Régie des Chemins de fer à voie de 0 m. 60 », with the character of railways of local interest.

Morocco is one of the most interesting countries from the point of view of electrification; although, as regards the railways electric traction has not yet been introduced except on heavy traffic standard gauge lines, an extensive plan of the general electrification of the country is at present in full development; the railways are considered as first consumers, which will render an economical distribution of electrical energy possible as the production increases, an impossibility if this plan had not been undertaken on such an extensive scale.

It is not, therefore, in the electrification of the Morocco Railways that are to be found the economic principles, which have led in the majority of cases to the electrification of other railway lines because, at the present economic period, the increase in the rate of interest, and consequently, on the capital expenditure, constitutes for electrification regarded from this point of view a serious obstacle, which is aggravated if it is remembered that, owing to the ever-increasing improvements in steam traction appliances, petrol engines, etc., there is very much less difference nowadays in the traction costs with the use on any one of these systems.

It is expected, however, that the impetus, which general electrification will give to the economic forces of the country in developing agriculture, industry and forestry will certainly bring a traffic which will compensate for the expense of electrifying the railways; on the other hand, electrification will bring the advantages which electric traction is known already to possess, to which ought to be added the elimination of the special difficulties encountered by steam traction in this country.

In point of fact, water is scarce , and generally of poor quality; it contains salts of magnesia and chlorides in large amounts, which frequently necessitates its treatment. On the other hand, the country is almost without coal, and this to an extent such that during the late war, as in Algeria and Tunis (countries in which there is no water power enabling electricity to be used economically), Morocco was obliged to go very short of coal; many firms had to use wood, oil residues, etc., and anthracite was replaced by charcoal for engines running on producer gas. In spite of the heavy cost, a few deposits of coal and lignite were worked; the workings were afterwards abandoned. Neither coal nor oil has yet been found in workable amounts in Morocco.

The principal hydro-electric power stations are being developed in the southern part of the Grand Atlas, and there are at present four stations producing energy, namely : two steam stations at Casablanca, another at Salé near Rabat, and a hydro-electric station at Sidi-Machon on the Oun-er-Rehia, which is able to cover peaks of 26 000 kw. utilising a fall of 18 m. (59 1/2 feet) with a maximum flow of 145 m^3 (1 520 cubic feet) per second; the distribution lines are 60 000 volts, the present consumption exceeds 40 million kw.-h., one quarter of which is consumed by the railways.

All the main railway lines will be electrified, both those already in existence and those projected (1 100 km. = 683.5 miles), electrification being limited for the present to the Casablanca-Rabat and the Casablanca-Kouriga lines (totalling 238 km. = 148 miles), the last mentioned line having a very important traffic in phosphates.

The system of electrification adopted is that of direct current at 3 000 volts; at the present time, the contact line is fed by four sub-stations which are semi-automatic and equipped with motor-generator sets. The type B+B locomotives of 1 000 H. P, are fitted with energy-regenerating brakes, which are of considerable importance as regards the phosphates lines. In addition, 560-H. P. motor coaches are also employed for passenger service.

On the secondary 0.60-m. (1 ft. 11 5/8 in.) gauge system, traction is generally effected by means of steam, and petrol motor trolleys are also used for carrying passengers and for the mails. It is probable, however, that the extension of the rural distribution of electricity, will enable the electrification of some lines on this system to be considered later.

Tunis. — The Tunis Regency possesses 2 100 km. (1 305 miles) of railways, 550 km. (342 miles) of which (towards Algeria) are operated by two private companies and have a considerable traffic. The system is metre gauge and belongs to the State; it is operated by the « Compagnie Fermière des Chemins de fer Tunisiens » (the Sfax to Gafsa Company only operates one line and a phosphate mine); it also has a considerable traffic, especially in phosphates, which are transported to the port of Sfax, where these Companies have large plants.

The greater portion of the Tunisian lines and their services are operated by steam; the Tunis-La Marsa line viâ Carthage and Goulette, and the direct Tunis-La Marsa line are the only ones electrified.

On the lines from Tunis to Feriana and Gafsa, metre-gauge, there is a considerable traffic in tourists, crossing a desert region [the oases are 50 to 60 km. (31 to 37 miles apart)], a journey lasting six days; the supply of water and fuel offers difficulties, and in addition on this line as on the other lines in this country, the poor quality of the feed water makes steam traction very expensive.

In the presence of these drawbacks, it was decided to try a Diesel electric locomotive, and this locomotive was put into service two years ago. The continuous power of the Diesel engine is 250 H. P. at 35 r. p. m., and the engine is coupled directly to a D. C. generator, which distributes the current to four self-ventilated motors, suspended by the nose (one to each axle). The continuous tractive force at the wheel tread is 1 520 kgr. (3 350 lb.) at 34 km. (21.1 miles) per hour, and the hourly force is 2 300 kgr. (5 070 lb.) at 21.5 km. (13.36 miles). The maximum pull attains 4 400 kgr. (9 700 lb.). The weight of the locomotive in working order is 39 tons, 8.1 tons of which corresponds to the electrical equipment, 1.2 tons to the battery, 7.8 tons to the Diesel engine, 19.4 tons to the mechanical parts and 2.5 tons to the six-days' supplies of fuel, oil, etc.

The Diesel engine is started up by accelerating it to ignition speed by means of the generator, which for this purpose is run as a series motor from the battery of accumulators (90 iron-nickel cells, 160 ampere-hours for a discharge period of 4 hours).

The auxiliary services include the control, fan and vacuum pump, fed either by the generator exciter or by the accumulator battery; the efficiency of the electrical equipment is 80 %.

This locomotive hauls a train of 80 tons at 60 km. (37.3 miles) per hour on the level, at 45 km. (28 miles) up gradients of 1 in 200, at 28 km. (17.4 miles) up gradients of 1 in 100, and at 21 km. (13 miles) up gradients of 1 in 67; on the last-mentioned gradients, trains of 126 tons may be hauled at a speed of 17 km. (10.6 miles) per hour.

The average oil consumption is 7.2 gr. per tonne-kilometre of the total weight of the train and 9.8 gr. per tonne-kilometre of the weight hauled. The average oil consumption is 0.22 gr. per tonne-kilometre.

Madagascar. — The railways at present operated in this country comprise 700 km. (435 miles) of metre gauge lines, connected at different points with a service of road transport, extending over 1 500 km. (932 miles) of roads. It is intended to extend the railways by constructing an auxiliary system of 0.60-m. (1 ft.-11 5/8 in.) gauge lines for working the more distant regions.

The main line of 36 km. (22.4 miles) Tamatave - Tananarive has gradients of 1 in 40, and curves of up to 50 m. (2 1/2 chains) radius. There is a very intense passenger and goods traffic on this line. The traction is effected by steam, with the difficulties inherent to the absence of coal, there being on the island only the deposits of Sokoa, the working of which is still being considered and presents, moreover, considerable difficulties, as well as that of the oil, which it appears occurs in the south-west part of the island.

For this reason, most of the locomotives are at present burning wood, a solution which does not comply with a traffic of any volume, and which will lead to the exhaustion of the forests of the region (6 to 7 steres [210 to 250 cubic feet] of wood are required as the equivalent of a ton of coal).

These reasons, as well as the need for

increasing the capacity on the most difficult sections of the main line, where the maximum loads with the most powerful locomotives (*Garratt* 2-6-0 + 0-6-2, with a total weight of 72 tons) are 180 tons, have led to consideration of the electrification of the line. For the present it has been decided to electrify 64 km. (40 miles) of the Tananarive-East Coast line, and this will be extended later perhaps to cover the larger part of the railways, the eastern range of mountains of the island being very rich in water power.

North America.

Canada. — Electrification of the public railways or of their branch lines is not very extensive in this country, which possesses 63 000 km. (39 147 miles) of lines of the standard gauge of 4 ft. 8 1/2 in. excepting the urban tramways, some suburban zones of small extent, and small interurban lines, exclusively used for passenger traffic, which have been electrified from the start, and which represent a total of 3 000 km. (1 864 miles) of lines in the provinces of Nova Scotia, New Brunswick, Quebec, Ontario, Manitoba, Saskatchewan, Alberta and British Columbia; only two small sections of the Canadian National Railways, the St. Clair Tunnel (5 km. [3.1 miles] at 3 300 volts, monophase current, 25 periods) and Mount Royal Tunnel (13 km. [8.1 miles] at 2 400 volts direct current) and the Montreal Yards of the Montreal Harbour Commission (31 km. [19.3 miles], 2 400 volts, D. C.) are operated by electricity.

Otherwise, and apart from the considerable development of the motor omnibus services, instituted by nearly 20 Electric Railway Companies, as a supplementary extension of these railways, it is interesting to note the development, following the example of the United States, of internal combustion motor coaches for making up light trains (of 100 to 300 tons), serving passenger traffic both on the main lines and on the secondary branch lines.

The working results show that these motor vehicles give receipts which are much greater than the expenditure, even for light traffic, and of course much greater than the corresponding receipts from the steam trains they have replaced.

Thus, for instance, since 1926, the Canadian National Railways have been running Diesel electric motor coaches for the passenger services on the 564 km. (350 miles) length of line from Edmonton (Alberta) to Saskatoa (Saskatchewan).

The first motor coaches put into service were of two types: very powerful (340 H. P.) articulated units capable of pulling two large passenger coaches, and single units (185 H. P.) pulling one passenger coach.

These two classes of units are equipped with Beardmore Diesel engines, having 8 and 4 cylinders respectively, coupled to D. C. generators, feeding the 4 or 2 traction motors of the coach.

The daily run of these vehicles varies from 230 to 564 km. (143 to 350 miles); for an annual run of about 90 000 motor coach-kilometrés (55 900 motor-coach miles) the net income is 0.44 per motor-coach-km. (0.71 per motor coach-mile) for the articulated motor coaches and 0.25 (0.40 per motor-coach mile for the single motor coaches.

As a result of the experience acquired with these motor coaches, the same Company later put into service a new type of single units, of high power (300 H. P.) capable of hauling two large capacity passenger coaches. These motor coaches are 22.5 m. (73 ft. 10 in.) long, and their total weight is 60 tons; in the body are located, in sequence, the driver's cab, the engine room, the luggage compartment, the passenger compartment with 37 seats and the second driver's cabin. The engine is also a Beardmore-Diesel (of a type resembling those employed on modern dirigeables), weighing 10 kgr. (22 lb.) per H. P.; the D. C., 600-volt generator supplies current to two traction motors.

Following the line of conduct marked by their previous experience, the Canadian National Railways have recently put into service between Brockville and Belleville (Ontario) an oil-electric locomotive, consisting of two 1 350 H. P. semi-units, of a total weight of 290 tons; each of the semi-units of the type 2-B + B-1 is equipped with a 12-cylinder heavy oil engine, driving the 4 traction motors through the agency of a D. C. generator; the locomotive can develop a pull of 45 tons on starting and 19 tons when running normally, and is capable of hauling a train of 2 500 tons at the speed of 30 km. (18.6 miles) per hour on gradients of 1 in 250 and at 65 km. (40.4 miles) on the level.

Other Railway Companies are also using petrol motor coaches, as for example, the Winnipeg Electric Company, which has several in service, of 120 H. P., 30 tons weight and a capacity of 59 places; this company is also running very extensive motor omnibus services.

The passenger traffic on the electric railways has to meet considerable competition on the part of motor omnibus transport; for this reason this passenger traffic has been abandoned by several companies. Others have taken the operation of the road services under their control as already stated.

According to 1927 statistics, of the 60 Companies running the urban and interurban electric railways, 26 have suffered losses, and only 7 have paid dividends, and this despite the increase of about 5 % of the total number of the passengers carried, a figure amounting to 781 398 000; the number of motor omnibus-km. covered by the railway companies running these services was 13 300 000 (8 264 000 motor omnibus-miles).

United States. — The conditions under which electrification has been developed in this interesting country are so special that it would be difficult to apply the consequences to the generality of cases often met with elsewhere. The United States also differ from European countries in the origin of the greater part of their interurban electric tramways. Very few of these have been operated by steam in the past, having on the contrary been established on a more or less economical basis for electric traction from the outset.

Excepting the large electrifications carried out by some of the main lines, the interurban electric railways may be classed in the following groups :

1. Extension of tramway system in order to reach a nearby city. These lines are generally the property of the tramway companies of one of the terminal cities, operating on the tramways in the cities served; the interurban section sometimes has its own roadway, and others use the ordinary roads.

2. Railways with the same conditions of track and traffic as the preceding case, but which belong to companies independent of the tramways : in this case they generally acquire the right of using the tracks belonging to these tramways.

3. Interurban lines with fast passenger

traffic, running on their own permanent way between the cities, where generally they also possess their own termini; these lines have likewise a passenger traffic and sometimes a goods traffic, associated with those of the steam or electric main lines.

4. Isolated sections or branch lines of the main lines, formerly operated by steam and which have subsequently been converted for various reasons, for example, the suppression of smoke, economy of operation, increase of passenger services, unity of working, etc. On these lines it is necessary to distinguish between two classes of sections : suburban sections near the large towns, with a considerable passenger traffic, and isolated sections in less populated districts.

The definition of secondary railway is only applicable to certain of the lines included in paragraph 3 (since many of them acquire an enormous passenger traffic in a short time) and a very small number of those considered in the second place in paragraph 4. In the classifation of secondary lines, electrification, considered as an improvement in the system of traction, only affects a few of the lines of the first group mentioned above — in view of the fact that most of them were constructed for electric traction at the outset — and others included in the second group; of the latter, some correspond to the extension of electrification on main lines or their branches, chiefly brought about by convenience of service, or to effect a general reduction of the working costs due to the unification of the system, as has happened with some branches of the Pennsylvania Railroad and the New York-New Haven and Hartford Railroad, with the result that the general features of their equipment are the same or resemble those of the main lines, independent of any other consideration; formerly, electrification was intended solely for a definite traffic, which may still belong to another undertaking, as is the case on the Dallas-Danton stretch of the Missouri-Kansas-Texas Railroad Company, whose lines electrified at 600 volts D. C., are used by the passenger motor coaches of the Texas Interurban Railroad, while the company owning the lines continues to run its trains by steam. It will be understood, therefore, that the consequences of such electrifications are not applicable to the subject of the present investigation.

Another feature of the electric railways included in the first three paragraphs is the constant competition caused by the vast extent and the perfect organisation of the new road transport services; this competition makes it necessary to be continually experimenting, and comparing technically and economically, new transport methods and material, which with the very detailed statistics relating to the results obtained, explains the great variety and the improvements acquired in the technique of engine stock.

It is interesting to glance at the situation of the electric railways of the United States as shown by the statitistics for the year 1928.

At the present time there are about 403 000 km. (250 000 miles) of public lines and railways operated by steam, all whith very few exceptions of the standard gauge of 4 ft. 8 1/2 in.; 10 % of these lines carry 50 % of the total traffic, and 90 % of these only use 50 % of the total number of kilometres given above, which indicates the load under which certain lines are operating. Electrification has been extended in a general manner to the latter, corresponding to 21 companies and 2 970 km. (1 845 miles) of lines (*i. e.* 0.75 %

of the total length) with 6 650 km. (413 miles) of electrified track, 507 electric locomotives and 1 911 motor coaches.

The companies possessing electrified lines and the system of electrification employed in each case are as follow :

Company.	Km. (Miles).	System.
Baltimore & Ohio Railroad	51 (31.7)	650 volts, D. C.
Illinois Central Railroad	61 (38)	1 500 volts, D. C.
Long Island Railroad	222 (138)	650 volts, D. C.
New York Central Railroad	102 (63.4)	650 volts, D. C.
New York, New Haven & Hartford Railroad.	236 (147)	650 volts, D. C.
New York, Westchester & Boston Railway.	43 (27)	11 000 volts, A. C. and 575 volts, D. C.
Pennsylvania Railroad	201 (125)	11 000 volts, A. C. and 650 volts, D. C.
Southern Pacific Railroad	80 (50)	1 200 volts, D. C.
Erie Railroad Company	55 (34.2)	11 000 volts, A. C.
Boston, Revere Beach & Lynn Railroad.	21 (13)	600 volts, D. C.
Boston & Maine Railroad	13 (8.1)	11 000 volts, A. C.
Butte, Anaconda & Pacific Railway	60 (37.3)	2 400 volts, D. C.
Chicago, Milwaukee & S. Paul Railway	1 081 (672)	3 000 volts, D. C.
Detroit, Toledo & Ironton Railroad	27 (16.8)	22 000 volts A. C.
Fort Dodge, Des Moines & Southern Railway.	236 (147)	1 200 volts, D. C.
Great Northern Railway	41 (25.5)	11 000 volts, A. C.
Michigan Central Railroad	8 (5)	650 volts, D. C.
Norfolk Southern Railroad	72 (45)	575 volts, D. C.
Norfolk & Western Railway	103 (64)	11 000 volts, A. C.
Northwestern Pacific Railroad	39 (24.2)	600 volts, D. C.
Virginian Railway	218 (135.5)	11 000 volts, A. C.

The first eight of the above-mentioned Companies possess a considerable suburban traffic. All of them generally employ electric traction for the passenger services and goods services if there are any; only four restrict it to the passenger services and four to the goods services.

In 1928 the new electrifications attained 430 km. (267 miles) of single track, and during this period, the consumption of the electrified railways approached 1 600 millions kw.-h. In addition, other important electrifications or extensions have been announced; for instance, the Pennsylvania Railroad is intending to electrify 523 km. (325 miles) of lines [with 2 100 km. (1 305 miles) of track] at 11 000 volts A. C.; the Reading Company, which is going to electrify all its lines of the metropolitan district of Philadelphia [70 km. (43.5 miles) of lines, attaining 177 km. (110 miles) of track] at 11 000 volts A. C.; the Delaware, Lackawanna & Western Railroad is electrifying the Morris-Essex line and branches with D. C. at 3 000 volts, obtained in sub-stations fitted with mercury vapour rectifiers, a total of 126 km. (78.2 miles) of lines with 280 km. (174 miles) of track, mainly suburban traffic, served by motor coach and trailer units of 920 H. P. Similarly, the electrification, already begun, of the Cleveland Union Terminal, will comprise the equipment, at 3 000 volts D. C., of 26 km. (16.2 miles) of lines (which will be served by 25 locomotives of 200 tons and

3 000 H. P.), and the construction of a new terminus station of 54 stories.

As previously mentioned, with the exception of a few small branch lines, equipped with plant similar to that of the main lines, none of the lines in the list given above has the character of a secondary line. Nevertheless, in view of the considerations set forth in the first part of the present report, the Boston, Revere Beach & Lynn Railroad presents some interesting features.

This line dates from 1875, in which year it was constructed on a 3 ft.-6 in. gauge, which is still in existence, and at the present time includes 21 km. (13 miles) of double track line and a total of 55 km. (34.2 miles) in the municipalities of Boston and Revere.

The line was operated at the outset by steam, and served for passenger traffic only, for which service this line possessed 26 locomotives and 97 coaches. The character of the line, subsequently relegated to the second class owing to competition, and on the point of being abandoned on several occasions, underwent a radical change when electrified at the beginning of 1928, in which year the number of passengers carried was 13 500 000.

The system adopted for the electrification was that of direct current at a pressure of 600 volts, with overhead contact line, fed by two fixed sub-stations and one portable sub-station, consisting of a complete 1 000-kw. set for feeding any section of the line which may require it.

The rolling stock comprises 60 motor coaches and 7 trailer coaches, all of which are old steam traction coaches suitably converted; the coaches which were to be used as motor coaches were fitted with a cab at each end, control and electro-air brakes; one of the bogies was replaced by a Brill truck fitted with two motors.

The cost of converting these coaches was $598 000 while the sub-stations cost $216 000 and the line $175 000; in addition $292 000 was spent in converting the stations, installing plant for automatic block signalling, etc.

Among the above-mentioned immediate plans for electrification, are included some lines of the Reading Company having the character of secondary lines, and which are at present operated by steam under the same conditions as the main lines; the steam locomotives at present employed on these lines have an adhesive weight of 45 tons and effect monthly runs of 3 500 km. (2 175 miles); steam traction, on all the main and secondary lines, costs 46 cents the tr.-km. (74 cents the train mile), not including depreciation of the stock (4.5 % per annum).

The object of the projected electrification is to meet the falling passenger traffic and to regain that which has been lost owing to competition, chiefly that of motor omnibuses. It is interesting to note that the Company has discontinued several steam traction passenger services on the secondary lines, having replaced them by motor omnibus services which connect with the trains on the main lines.

Apart from the lines already mentioned, there exists in the United States about 65 000 km. (40 400 miles) of track of electric urban and interurban railways, operated with electric traction since the lines were laid down. In 1928, the extension of the said urban railways was 248 km. (154 miles) and that of the interurban railways was 84 km. (52 miles). Similarly, 1 026 km. (638 miles) of urban lines and 348 km. (216 miles) of

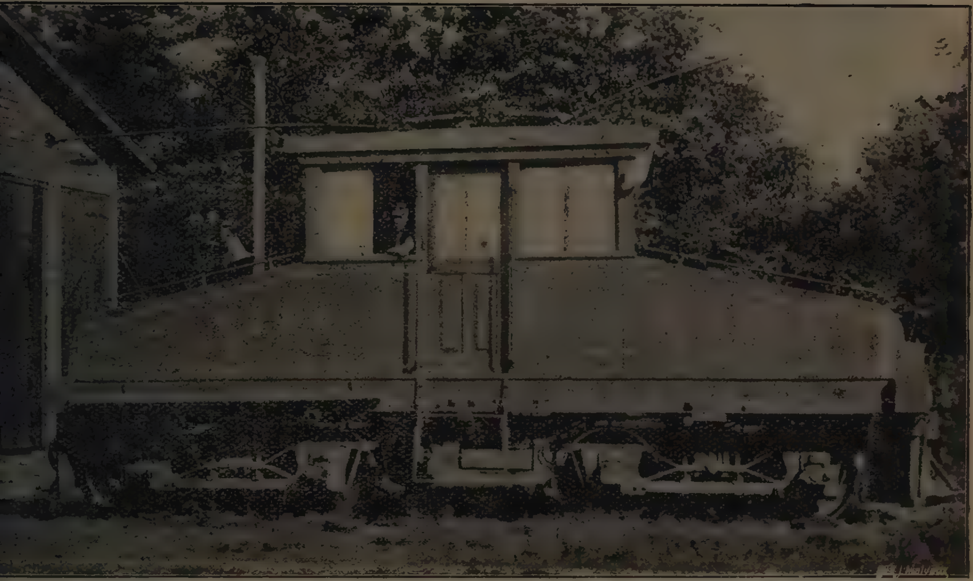

Fig. 5. — 31-ton, 400-H. P. electric locomotive of the Fonda, Johnstown and Gloversville Railroad.

interurban lines were reconstructed (the traction stock purchased by all the electric railways was 31 locomotives, and 428 urban and 213 interurban coaches).

The Fonda, Johnstown & Gloversville Railroad Company may be mentioned as a remarkable example of one of these interurban railways of a secondary character, referred to at the outset of the present report. This normal gauge railway operates electrically the double track interurban line between Gloversville and Schenectady (N. Y.), 53 km· (33 miles) long, and the single track branch line to Fonda, 16 km. (10 miles) long, the first exclusively with passenger traffic, and the second with passenger traffic, mails, and fast traffic. It possesses, in addition, the Fonda-Northville line and the branch line to Broadalbin, operated by steam traction, the urban lines in the towns through which it runs, and the right of running trains on other electric lines belonging to other companies. At Fonda, Amsterdam and Schenectady, it connects with the lines of the New York Central Railroad.

The electric operation is effected by means of 31-ton locomotives, equipped with four 100-H. P. motors, and motor coaches of 40 tons with 56 places, taking power at 550 volts, D. C., from a single suspension contact line, fed by three transformer substations. The annual cost of the electric traction is 25 cents per coach-km. (40 cents per coach-mile), for a total run of 2 113 000 coach-km. (1 313 000 coach-miles); power costs 1 cent the kw.-h. in D. C., and 0.55 cent the kw.-h. in A. C.; the total consumption is 7 437 000 kw.-h. per annum.

Among the railways just discussed are also included those for special traffic, such as the River Lumber Company's system, constructed for the transport of wood in California. The line is normal gauge and 28 km. (17.4 miles) long, and about 25 000 wagons are handled in a season. It is electrified at 1 500 volts, D. C. and possesses two 61-ton locomotives and an automatic sub-station equipped with two 1 000 kw. rotary convertors. The overhead line possesses the special feature that the contact wire is 3 m. (9 ft. 10 in.) from the centre of the track in order to allow a free passage to the loads of wood. Moreover, since the line is installed at one side or the other of the track, according to the irregularities of the permanent way, the locomotive collector can be turned from one side to the other by means of cylinders of compressed air.

Another interesting feature of the electric railways of this country lies in the discontinuation of lines which are poor or are open to excessive competition. In 1928, 27 companies abandoned together 944 km. (587 miles) of lines, and of these companies, 10 replaced the electric services by motor omnibus services.

The lines partially abandoned amount to 952 km. (592 miles), of which 531 km. (330 miles) belonged to interurban lines, that is to say, altogether 1 896 km. (1 178 miles) of lines were abandoned, of which 754 km. (469 miles) were replaced by motor omnibus services; this replacement corresponded to 557 km. (346 miles) of interurban lines.

It follows, then, that not only has the motor omnibus solved the transport problem in many districts where the volume of traffic did not justify the construction of a railway, but over and above this it has managed to cause important lines or sections of lines to be discontinued. Hence the growing importance for electric railway companies of running motor omnibus services, either as supplementary or feeders to their lines, or as a means of profiting by a traffic, which would not use the railway, without making any excessive expenditure.

At the present time about 330 urban and interurban electric railway companies are operating road services, constituting a system of 37 000 km. (23 000 miles) of lines, served by 11 000 motor omnibuses. In 1928, the electric railways extended their motor omnibus services on 8 000 km. (4 970 miles) of lines, of which 1 900 km. (1 180 miles) were urban and 6 100 km. (3 790 miles) were interurban; they have acquired 2 350 motor omnibuses, of which 550 are of the petrol-electric type.

Forced by competition, other electric railways are replacing their old stock of heavy coaches, served by 2 employees, by light modern coaches of the *one-man-operation*, type with the expectation of reducing considerably the cost of traction and of attracting the passenger traffic.

The Gary Railways, for example, on the interurban Gary-Hammond (Ind.) line of 16 km. (10 miles) have replaced the old 23-ton coaches by coaches weighing 17 tons (of which 8 tons corresponds to the body, 5 tons to the trucks, and 4 tons to the electric equipment) of the *one-man* type, 160 H. P., provided with 4 motors, having a seating capacity of 46 places, and able to attain speeds of 75 km. (46.6 miles) per hour.

With the use of this material, the cost

of the coach-km. has fallen from 17.8 cents to 13·5 cents, i. e. by 24 %, on the 37 km. line from Gary to Valparaiso, which was losing money, and the receipts were immediately increased by 41 %. The maintenance costs of the coaches fell from 1.3 cents per coach-km. to 0.5 cent, i. e. 38 %; the labour expenses were reduced by 30 %, and the remainder of the reduction corresponds to the saving in the power consumed. In addition, this company is running motor omnibus lines parallel to its railway lines, so as to avoid the competition of others.

Similarly, the Indiana, Columbus & Eastern Traction Company, which had a line on the point of being abandoned, has been able to effect a considerable saving by replacing its old 40-ton coaches by others of 25 tons; the power consumed fell from 2.6 to 2.1 kw.-h. per coach-kilometre and the maintenance costs from 2.6 to 1.2 per coach-kilometre.

The Chicago & Joliet Electric Railway, with new interurban coaches of 17 tons, 52 places, equipped with four 35-H. P. motors, is effecting a considerable saving owing to the better efficiency of the modern engines : less upkeep expenses and a saving of 40 % on the power consumption.

The Kansas City, Leavenworth & Western Railway has replaced its old 34-ton interurban coaches by new coaches of 15 tons and 52 places.

The Milwaukee Electric Railway operates the interurban railways of the Milwaukee district (several of these belonging to the original 1 200-volt system have been converted) with a very extensive system at 600 volts, D. C., fed by automatic sub-stations equipped with mercury rectifiers. The trains composed of one motor coach and one trailer coach run at a maximum speed of 96 km. (60 miles) per hour; motor omnibus road transport services are also run as supplementary to the system.

The Washington, Baltimore & Annapolis Railroad, competing with the parallel lines of the Pennsylvania Railroad, employs for the interurban services, articulated units, weighing 53 tons, with a capacity of 94 places and fitted with 4 motors (2 on each outside bogie); the tension employed is 1200 volts, D. C., with speeds of 96 km. (60 miles) per hour.

The Houston North Shore Railway, as also the Chicago, North Shore & Milwaukee Railroad, have put into service luxury interurban coaches in order to retain and attract the passenger traffic. Other Railways, such as the Southern Pennsylvania Traction Company (Delaware) are rebuilding their old coaches to adapt them to the *one-man* operation and to make them of use for passenger service. The statistics for different electric railways that have renewed their engine stock show that the weight of the latter may be reduced by 50 % as compared with the weight of the stock acquired 15 or 20 years ago. The cost of traction has been reduced on the average from 24.7 cents to 14.7 cents per coach-km., 7.5 cents correspond to the saving effected on the power consumption (with an average reduction of 55 %) and 2.5 cents to the expenses on maintenance (which have been reduced 50 %) and attendants; the latter are reduced 28 % by the use of the one-man coach.

Apart from this saving, the Kentucky Traction and Terminal Company reports a reduction of about 35 % of the maintenance costs of the track, the material of which has its life extended by 78 %. The same company, who have replaced their old coaches by others of the one-man type, weighing 60 % less, has also put into service motor goods vans of a light type (15 tons), equipped like the passenger coaches with four 25-H. P. motors. One or two employees are carried, according as to whether goods are taken up or not during the journey.

The recent improvements in internal combustion engines have led to their being employed for traction on railways with light traffic, particularly passenger traffic, where it has been necessary to strive to effect a saving on the expenses of steam traction (too heavy to run small trains or to meet competition) and on those railways where the local conditions were not economically in favour of electrification.

The relatively high power required, coupled with the high efficiency, reliability and flexibility in the working of modern electric equipment, point to electrical transmission as the most suitable. Following this line of argument, the development of petrol, electric, petrol-electric or oil-electric (Diesel type) coaches is considerable in the United States, so much so that the American Electric Railway Association has a committee for studying its applications and its results.

The number of these coaches at present in service exceeds 400 (117 were put into service during 1928) and they differ greatly in character: The New York, New Haven & Hartford Railway, the Philadelphia & Reading Railroad (Trenton) and others employ petrol-electric motor coaches with 48 places, equipped with a Brill-Westinghouse gas-electric engine of 250 H. P., and four traction motors. The Pennsylvania Railroad, the Chicago & North Western, and the Chicago, Burlington & Quincy Railway employ this system of traction to a large extent on the branches of their lines operated by steam traction.

The Boston & Maine Railroad has put into service quite recently motor coaches of this type, on which a special carburettor is employed to start up the engine on petrol until it attains a speed of 400 r. p. m.; the engine is then changed over to the fuel provided, which is a distilled product. The engine develops 275 H. P. at 1 000 r. p. m. and with the procedure indicated above, it is expected that a saving of 30 % to 50 % will be effected in the cost of fuel; the petrol supply is only 200 litres (44 Brit. gallons).

The equipment of the Chicago, Rock Island & Pacific Railway and of the Union Pacific Railroad is remarkable not merely on account of the use of distilled fuel, but also because of the high power of the last coaches to be put into service, some of which are fitted with two 400-H. P. motors; so that the units are also utilised for hauling light goods trains, thus eliminating entirely the steam service on some branch lines.

It should be mentioned that all these types of motor coaches are capable of hauling at least one coach of considerable capacity; it is also possible to couple them up to form multiple units, in a way similar to that obtained in current practice with electric motor coaches, if the traffic demands the formation of heavier trains.

Following the same order of ideas, 13 oil-electric locomotives of 300 to 600 H. P. were supplied to different railways of the United States during 1928.

Mexico. — The electrification of the railways (in course of extension) attains in this country about 103 km. (64 miles) of the main standard gauge line of the Mexican Railway between Esperanza and Orizaba; the system employed is D. C. at

3 000 volts; an important passenger and goods traffic is served by locomotives of 140 tons and 2 700 H. P. (the old steam locomotives used heavy oil as fuel).

The line of the Potosi Railway, 0.760 m. (2 ft.-6 in.) gauge, with a goods traffic only, which serves the Potosi mines, has also been electrified on a length of 25 km. (15.5 miles) between the said mines and Morse Smelter.

The object of this electrification, effected with D. C. at 600 volts, was to increase the capacity of the line, which has very steep gradients, and to cheapen its operation, mainly by means of the regeneration of energy, which attains 12 %. The service is effected with six 24-ton, 400-H. P. locomotives; the annual traffic amounts to 517 000 wagon-km. (321 250 wagon-miles), and the power consumption is 2.45 kw.-h. per wagon-km. (3·94 kw.-h. per wagon-mile) measured on the high tension side of the sub-stations.

All the other lines are operated by steam, whether main lines or secondary. Electric traction is employed on a few extensions of the urban tramways, and petrol tractors are also used for light traffic on some steam lines·

Cuba. — The most important railway system belongs to the United Railways of Havana, possessing 124 km. (77 miles) of suburban lines (Havana to Guines, Rincon and Guanajay) electrified at 600 volts, D. C., and carrying a heavy traffic.

In addition there are a number of small secondary branch lines distributed throughout the system, on which it is necessary to maintain a regular passenger service, which was very heavy with steam traction. At the beginning, petrol motor coaches of 12 tons, equipped with a 40-H. P. motor capable of attaining speeds up to 60 km. (37.3 miles) were put into service. Very satisfactory results have been obtained with these coaches; the maintenance costs are low, and the material runs up to 160 000 km. (100 000 miles) between consecutive overhaulings.

The capacity of these coaches is limited, however, and for this reason petrol-electric motor coaches, weighing 41 tons, with an accomodation of 50 places, comprising a luggage van and a lavatory, have been put into service quite recently. The coaches are equipped with a 275-H. P. engine coupled to an electric generator supplying current to two traction motors, mounted on one of the bogies, and can attain speeds of 75 km. (46.6 miles) per hour. On the main lines, they pull two passengers coaches, and have thus enabled several steam trains to be dispensed with; the daily runs attain 320 km. (200 miles) and the traction costs are approximately half those of the steam trains which they have replaced.

The Hershey Cuban Railway is also electrified between Havana and Matanzas (90 km. = 56 miles) which, with other branch lines, makes a total of 138 km. (86 miles) of electrified track. This railway, which has gradients of 1 in 40, when it was first constructed only served the sugar mills of Central Hershey with about 56 km. (35 miles) of track; after electrification it was extended to Havana, Matanzas and branch lines and at the present time, apart from the important traffic in cane and sugar, it possesses a general goods and passenger traffic, Havana-Hershey-Matanzas.

The old steam locomotives, with an adhesion weight of 20 to 40 tons burnt coal and oil under very unfavourable conditions, for which reason it was decided to construct a thermal power station of 7 500 K. V. A., which not only feeds the railway sub-stations, but provi-

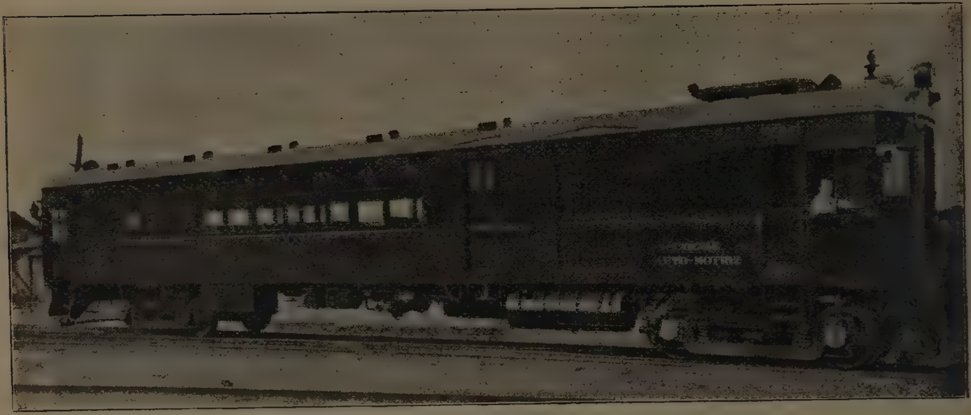

Fig. 6. — Petrol-electric motor coach of the United Railways of Havana.

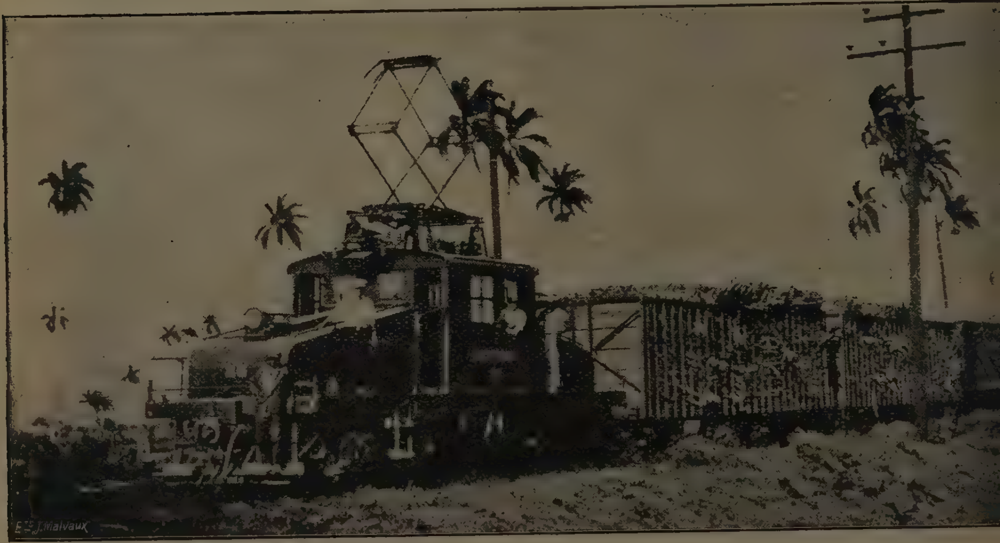

Fig. 7. — 60 ton-electric locomotive of the Hershey Cuban Railroad, hauling a train of sugar cane.

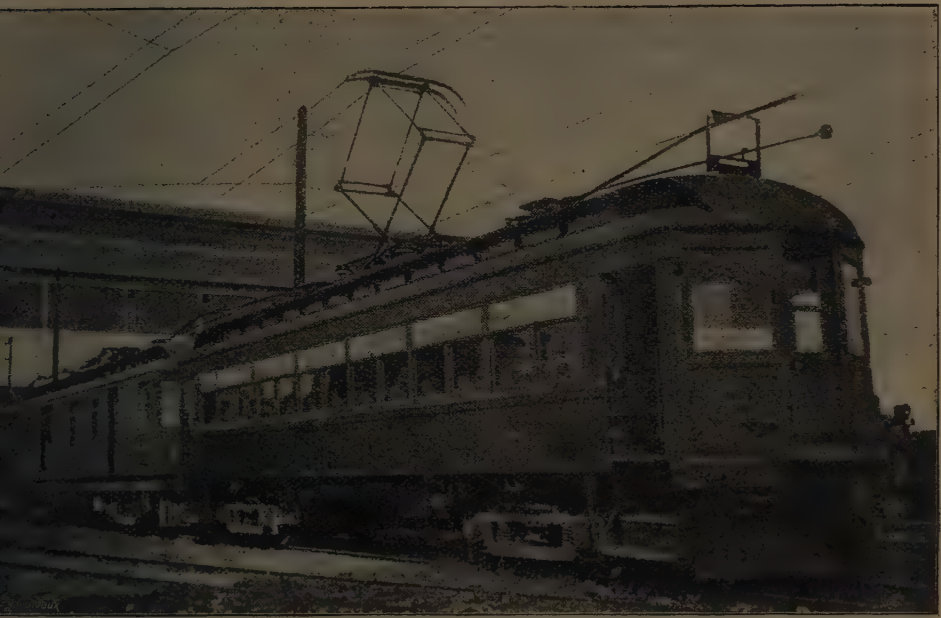

Fig. 8. — Passenger train of the Hershey Cuban Railway.

des energy to the town of Matanzas, and other towns lying near the railway, through 35 000 volt transmission lines; the fuel used at the power station is steam-atomised oil.

The system employed for electrification is that of D. C. at 1 200 volts, with overhead contact line fed by a 2 000-kw. sub-station and two 1 000 kw. sub-stations, all equipped with rotary convertors. The traction stock consists of three 60-ton locomotives, type B+B and 14 passenger motor coaches, of 29 tons, with accomodation for 50 passengers (four of which coaches having compartments for the mail and luggage), equipped like the locomotives with four motors, and capable of attaining a speed of 65 km. (40.4 miles) per hour.

Since the whole of the present line has never been operated with steam traction, and since the traffic is no longer the same, it is impossible to give any exact comparative figures. It has been possible to ascertain, however, that the amount of oil previously burnt for a harvest of sugar cane (1 800 to 2 000 tons are brought daily from the fields) is the same as that used at present, not only for hauling the sugar cane trains, but also for driving of goods the mills, for the daily haulage of two or four trains of goods and 12 of passengers, as well as for the production of 3 000 000 kw.-h.

per annum, intended for other industries than that of the railway.

Electrification has also enabled 10 water stations to be dispensed with, the upkeep of which cost $10 000 per annum.

Central America.

Guatemala. — The construction and electrification of the Felipe-Santa Maria section of the Los Altos Railway was completed in 1928. This section connects the Guatemalan plateau with the present railway crossing the southern part of this country and the tropical low country.

The construction of this line was begun in 1924; its length is 45 km. (28 miles), between the town of Felipe, round which it runs, and that of Quezaltenango; ten intermediate stations have been built in addition to the termini, as well as numerous bridges and a 12 000 H. P. hydro-electric power station near Santa Maria [1 650 m. (5 400 feet) altitude] which by means of a three-phase transmission line of 50 000 volts, will feed the railway sub-stations and also transmit electric power to Guatemala and other centres.

The system of electrification adopted is that of D. C. at 1 500 volts, with overhead contact line, fed by two transformer sub-stations, one at Santa Maria and the other at Quezaltenango.

The engine stock consists of six passenger motor coaches and eleven goods wagons, as well as two petrol motor coaches which will be used on future extensions and as a reserve. The line has gradients attaining 9 %; for this reason, the coaches are provided with four kinds of brake : compressed air, rheostat, electro-magnetic and hand.

Contrary to the usual custom in Central America, the gauge is 4 ft. 8 1/2 in. The electrification projected in this country is restricted to this line (despite the fact that it is hoped that the extensive cocoa and coffee plantations, and the important mines in the regions served by the line will give an impetus to the development of traffic).

The other lines in Guatemala mainly employ oil as fuel for steam traction, under very unsatisfactory conditions, owing to the lack of fuel in this country.

Costa Rica. — In this country, electrification of the State railway between the capital San José and the port of Puntarenas is being carried out. The length of this line, on which there are steep and long gradients, is 129 km. (80 miles) and its gauge is 3 ft. 6 in.

The system used for electrification is monophase, 20 cycles, and 15 000 volts on the contact line; the power is produced by a hydro-electric station, equipped with three turbines with 2 000 K. V. A. three-phase generators, the transformation into mono-phase current being effected in a special sub-station.

The overhead line is catenary with a copper contact wire 80 mm^2 (0.123 sq. inch) in section and a bronze supporting cable 30 mm^2 (0.041 sq. inch) in section.

The trains will be drawn by eight locomotives, weighing 54 tons, each equipped with four monophase motors, with an hourly rating of 145 kw. with tram-type suspension, and gear transmission. The locomotives are provided with compressed air brakes, and the arrangement of the axles corresponds to the notation A1A+A1A, the free axles being interposed between the driving axles, in order not to exceed a maximum load of 12 tons per axle.

It is intended to put them into service during 1930.

South America.

The railway systems of the various States of South America represent a total length of 93 000 km. (57 800 miles) of lines for an area of 18 800 000 km² (7 259 000 sq. miles), with a population of about 70 000 000 inhabitants.

The conditions under which the railways are established, their organisation and management are as varied as those of the different regions through which they run. Different gauges are met with in all these countries; the one most frequently used is that of 1 m. (3 ft.-3 3/8 in.) with a length of 51 % of the total for all the railways; those coming next in importance are the 5 ft.-6 in. gauge with 27 %, and 4 ft.-8 1/2 in. gauge with 10 % of the total length.

Very few definite efforts have been made as yet towards unification of gauge; so far, the Paraguay Central Railway alone has rectified its track to the gauge of 4 ft.-8 1/2 in. so as to connect the capital with Buenos Ayres. It is also intended to convert the line of the Antofagasta & Bolivia Railway in Chili to the metre gauge, to bring it into line with the Bolivian railways.

Brazil and Bolivia may be classed as countries of the metre gauge, whereas Uruguay and Paraguay prefer to use the 4 ft.-8 1/2 in. gauge and Peru employs gauges varying from the last-mentioned down to 1 ft.-11 5/8 in.

The lines of the Northern Republics vary little in gauge. Chili uses five different gauges, which is not so illogical as it might at first appear because, of the lines of 4 ft.-8 1/2 in. gauge and 1 m. (3 ft.-3 3/8 in.) gauge, joining at Calera (between Santiago and Valparaiso), the first runs towards the south and the second towards the north of the Republic. Lines of 2 ft.-6 inch gauge are met with more to the north of the country, while lines of the other gauges are used mainly for the nitre fields, their traffic between the mines and the coast being almost exclusively in this product.

Argentina has also three gauges of main lines, but these run through different territories, so that the drawbacks inherent to this variation in gauge are minimised. Both in this country and in Uruguay, Paraguay, Bolivia and Peru, most of the lines are operated by private companies, while in Chili and Brazil the State takes the greater share in the operation of the railways.

The international lines at present in existence number three in the Argentine Republic, running respectively towards Chili, Bolivia and Paraguay, one between Chili and Bolivia, and the other between Paragúay and Brazil. Peru, Ecuador, Colombia and Venezuela have no direct communication with the other countries of the continent.

The most important railway system belongs to Argentina, which possesses 38 500 km. (23 923 miles) of lines, of which 22 000 km. (13 670 miles) are 5 ft.-6 in. gauge, 11 800 km. (7 332 miles) are 1 m. (3 ft.-3 3/8 in.) gauge and 3 000 km. (1 864 miles) are 1.445 m. (4 ft.-7 11/16 in.) gauge, the remainder having different gauges, which in general approach 0.60 m. (1 ft.-11 5/8 in.).

Then, in order of importance come Brazil, with 32 000 km. (19 884 miles) of lines [28 000 km. (17 400 miles) of which have a gauge of 1 m. (3 ft.-3 3/8 in.)], and Chili with about 10 000 km. (6 210 miles) distributed mainly between the gauges of 5 ft.-6 in. (3 200 km. = 1 988 miles), 3 ft.-3 3/8 in. (2 900 km. =

1 800 miles) and 2 ft-6 in. (1 500 km. = 932 miles).

The definition of secondary railway is very difficult to apply on this continent, where the conditions vary greatly, and where much remains to be done as regards the railways. The best known secondary lines are probably those of the Buenos Ayres Great Southern Railway, forming a system of 330 km. (205 miles) of 0.60 m. (1 ft.-11 5/8 in.) gauge, operated mainly for agricultural purposes.

Electrification of the railways is still far from extensive and is restricted to a few lines having a very heavy suburban traffic or other lines or sections of main lines, few in number, on which local difficulties have to be overcome. There is reason to hope, however, that the favourable conditions encountered in many regions will serve as a stimulus to the electrification of the railways.

Traction is generally effected, therefore, by steam, petrol tractors being also used in special cases; on the above-mentioned secondary line, steam locomotives are employed on the lines where the traffic is the heaviest, while in the regions which are chiefly agricultural, small petrol tractors are emplyoed.

In what follows, several features of the lines electrified in this country will be given.

Argentina. — Electrification in this country is restricted to the suburban railways of Buenos Ayres, operated by the Central Argentine Railway Companies and the Buenos Ayres & Western Railway.

The lines electrified by the first of these two companies have a length of 56 km. (35 miles) and a 5 ft.-6 in. gauge, with a traffic which is entirely passenger, served by motor coaches of about 500 H.P., and a weight of 51 tons, in conjunction with 60 traier coaches; the system employed for electrification is D. C. at 800 volts, with third rail contact.

The second of the railways mentioned operates about 41 km. (25.5 miles) of lines (126 km. [78.2 miles] of tracks, with an intense suburban traffic served by more than 300 trains daily), on which there are gradients attaining 1 in 26 and large tunnels. The gauge is also 5 ft.-6 in.; the electric traction uses current at 800 volts, with third rail, except on the tracks in the zone of the port, where there is a contact line for dealing with goods. This contact line is used by locomotives of 920 H. P. and 62 tons weight.

The passenger services are effected by trains of motor coaches and trailer coaches, the former weighing 56 tons and producing 800 H. P. per hour.

Brazil. — Apart from the important suburban extensions of the tramways of the cities of Rio de Janeiro and St. Paul, etc., practically constituting interurban lines, the most important electrification is that carried out by the Paulista Railway Company on a length of 286 km. (178 miles) (between Jundiahy and Rincao), on the main 1.60 m. (5 ft.-3 in.) gauge line. The line is very irregular and has numerous steep gradients, which coupled with the lack of coal and the need for increasing its capacity, has stimulated the company to transform the traction system.

The system used is that of D. C. at 3 000 volts, the contact line being fed by 8 sub-stations (one of which is automatic) equipped with motor-generator sets, giving a total continuous power of 22 500 kw.; electric passenger, goods and shunting locomotives are used, the first mentioned being of the 1-C + C-1 type, weighing 134 tons and capable of attaining maximum speeds of 110 km. (68.3 miles) per hour.

The saving obtained in the cost of traction is remarkable; in 1928 it was 58.8 % in the expenses per train-kilometre and 77.9 % of the cost of the tonne-kilometre hauled, as compared with steam traction; the difference between the coefficients is explained as due to the increase in the traffic which took place on electrification.

Quite recently, the electrification of the Western of Minas was completed. This railway, belonging to the Minas State, runs between Barra Mansa and Augusto Pertana, a length of 73 km. (45.4 miles). The D. C. system at 1 500 volts has been applied; the gauge is 1 m. (3 ft. 3 3/8 in.) and the traffic is generally passengers and goods. The direct current, high tension system will also be used in electrifying the Western Union Railway and the Central of Brazil Railway.

Chili. — Among the different lines or sections which have been electrified in this country, the most important are those of the Chilian State Railways on the Santiago to Valparaiso line (187 km. = 116 miles) and the branch line to the Andes (49 km. = 30.5 miles), a total of 232 km. (144 miles) of 5 ft.-6 in. gauge lines. The steep gradients on this line (1 in 44), the lack of coal and its poor quality, and the necessity of increasing the capacity of the line for its important traffic in passengers and goods, were the reasons for deciding on electrification, which has been effected with D. C. at 3 000 volts, the contact line being fed by five transformer sub-stations, each equipped with two motor-generator sets of 2 000 kw. The service is made by 39 electric locomotives, which have replaced more than one hundred steam locomotives. Of these locomotives, 6 are passenger locomotives of the 1-C + C-1 type, with a capacity of 2 250 H. P. and a weight of 130 tons, fitted with regenerative braking, and capable of attaining 100 km. (62 miles) per hour; they have locomotives of the type B + B of 1 500 H. P. and a weight of 80 tons, intended for local passenger trains, which attain a speed of 90 km. (56 miles); 15 goods locomotives of the type C + C, of 1 680 H. P. and 115 tons weight, and 7 shunting locomotives of the type B + B of 480 H. P. and 67 tons, make up the figure given above.

Another important section electrified is that of the Chilian section of the Trans-Andian Railway, which links up at the Andes with the line from Santiago to Valparaiso; this section has a length of 70.5 km. (43.8 miles) up to the Argentine frontier, after which the line (metre gauge) continues until it reaches the town of Mendoza (Argentine), with an additional length of 179 km. (111 miles). The section on Chilian territory has five rack rail sections with maximum gradients of 1 in 12.5, and three sections of adherent traction with maximum gradients of 1 in 40; the minimum curves have a radius of 100 m. (5 chains).

Electrification was carried out with the object of being able to retain traffic all the year round, a difficult matter for steam traction in the Cordillero Pass of the Andes, at a height of 3 190 m. (10 460 feet) (the interruptions in the service often attained sixty days) and of increasing the efficiency of the line by avoiding the transport of coal. It is not the density of the traffic which has justified the electrification in question, seeing that, in each direction, there are only two goods trains a day and a passengers train twice a week. The system selected was that of D. C. at 3 000 volts; the line is fed by one sub-station equipped with two motor-generator sets of 1 500 kw.

The electric locomotives used are mixed, rack and adhesion traction, and pull trains of 150 tons in the direction from east to west and of 200 tons in the opposite direction; their hourly capacity is 1 410 H. P., distributed among six motors connected by groups of two in series; their total weight is 85 tons, with a maximum load per axle of 12 tons. The arrangement of the axles corresponds to the notation 1-C + C-1; four motors mounted on the bogie frames engage 6 axles (adhesion traction) by means of coupling and connecting rods; the two other motors actuate the toothed wheels of the rack rail drive. The attainable speeds are 40 km. (25 miles) per hour on the sections with adhesion traction, and 16 km. (10 miles) on the rack sections. The locomotives are provided with 3 brakes : compressed air, electrical and on the toothed wheels of the rack rail drive.

In addition to the two instances of electrification just mentioned, the Chile Exploration Company possesses at Chuquimata, 25 km. (15.5 miles) of lines electrified at 600 volts, with third rail, with which a traffic entirely of goods is effected by means of 9 locomotives of 69 tons, and 560 H. P.; the Chilian Nitrate Railways have 32 km. (20 miles) of lines also electrified for goods services, as well as the Anglo-Chilean Cons. Nitrate Corporation (40 km. [25 miles] at 1 500 volts, D. C.) and the Bethlehem Chili Railway (24 km. [15 miles] at 2 400 volts, D. C.). All this electrification has been carried out owing to local difficulties encountered with steam traction, especially owing to the lack of water and the poor quality and scarcity of coal.

Venezuela. — The only electrification which has been effected in this country is that of the line from Caracas to La Guira, 36.5 km. (22.7 miles) long with passenger and goods traffic; electrification is with D. C. at 1 500 volts and its main object has been to increase the speed of the passenger trains, in order to be able to compete with the motor omnibus services which run parallel.

Oceania.

Australia. — The gauges vary so considerably in this continent [from 0.61 m. to 1.60 m. (1 ft. 11 5/8 in. to 5 ft. 3 in.)] that the line from Adelaide (South Australia) to Melbourne (Victoria) 778 km. (483.5 miles) long, gauge 5 ft. 3 in. is the only one connecting two capitals of Australia without having to change trains owing to difference in gauge.

The railways are operated generally by steam, on both the main lines and secondary lines; on many of the latter, however, special methods of traction have been introduced with the object of effecting a saving in the light traffic, especially that of passengers. Thus, for instance, the Queensland Railways, in order to economise on their secondary lines and develop the passenger traffic, subject to considerable competition owing to the increase in road transport, are employing petrol motor coaches and trailer coaches of the motor omnibus type.

The New South Wales Government Railways have also adopted petrol motor coaches on various secondary branches of their lines, enabling them to give to the inhabitants of a little populated country a frequent and economical service, which would not have been justified by any other means. Lately, they have put into service, with considerable success, up to 30 petrol-electric motor coaches with two bogies, the service of which alternates with heavier mixed steam trains; the consumption of these coaches, making a daily run of 90 to 330 km. (56 to 205 miles) at the speed of 40 km.

(25 miles) is 2.35 litres of fuel per km. (0.83 British gallon per mile). The run between two consecutive stoppings for inspection and repairs amounts to 100 000 km. (62 100 miles).

Other railways of narrow gauge are using, chiefly for the sugar industry services, small internal combustion engine locomotives, running on petrol or ethyl alcohol, with a power of 80 to 100 H. P.

The electrification of the railways is limited at present to the suburban lines of the cities of Sydney (New South Wales Government Railways) and Melbourne (Victoria Government Railways).

The first has a length of 336 km. (209 miles) and a gauge of 4 ft. 8 1/2 in., and is equipped with D. C. at 1 500 volts, which voltage has also been adopted for electrifying the metropolitan railway of Sydney. The sub-stations, numbering 23, receive energy from two thermal power stations of 105 000 kw. and 34 000 kw., respectively, and are fitted with rotary convertors and mercury vapour rectifiers; some of them are equipped with automatic control. The service is effected with 550 motor coaches and 550 trailer coaches, forming trains of six units, which are able to run at the rate of 160 an hour (80 in each direction); the motor coaches are metal, weigh 49 tons, and are equipped with two motors of 1 500 volts and 360 H. P. hours. The traffic is very intense attaining 120 million passengers per annum. At the central station of Sydney, the number of passengers during the periods of peak loads reaches 40 000.

The electrification of the Melbourne suburban railways covers a length of 262 km. (150 miles) of lines (with 652 km. = 405 miles of tracks) of the 5 ft.-3 in. gauge, equipped to utilise D. C. at 1 500 volts; the energy from a 60 000-kw. thermal power station is distributed in 15 transformer sub-stations, equipped with 1 500-volt rotary convertors of 1 500 kw. to 3 000 kw. per unit. The service is effected by 200 motor coach and trailer coach units, the motor coaches being equipped with four 140-H. P. motors; two 760-H. P., 51-ton locomotives are also used for the goods services. The number of passenger trains is 2 570 daily, which give 62 790 000 coach-km. (39 016 000 coach-miles) per annum, with a consumption of 2.30 kw.-h. per coach-km. (3.72 kw. per coach-mile) and 30.5 kw.-h. per tonne-km. (49.9 kw. per Engl. ton-mile).

New Zealand. — Apart from the tramway lines and their extensions, electrification is limited to the Otiro-Arthur-Pass section (13.5 km. = 8.4 miles) of the line from Christchurch to Littelton of the New Zealand Government Railways, on which steep gradients are encountered (up to 1 in 33) and 8 km. (5 miles) of tunnel. The line, 3 ft. 6 in. in gauge, has the character of a main line since it serves all the traffic between the North and South Islands.

Electrification has been carried out with D. C. at 1 500 volts; for the passenger and goods traffic six locomotives are employed, each of 51 tons and 680 H. P.

III.

The rapid survey which has been made during the preceding chapter, gives some idea of the point which the electrification of railways, considered as the transformation of the original system of traction, has reached. This limitation is still greater when is is a question of secondary lines, in which economy in the first costs and the working costs is a factor of paramount importance.

In general, as we have already had the

occasion to see, steam is the usual mode of traction on secondary lines of normal or narrow gauge. Apart from the question of economic working, steam traction undoubtedly adapts itself much better than any other form to the most varied local conditions and, in addition, the use of material coming from other lines often enables a considerable saving to be effected in the first costs, although in the second place, this same saving may be the cause of the lingering death which many secondary lines drag out.

In many instances, electric traction may be distinctly superior to steam traction, especially as regards running expenses (not including-depreciation of material), of which one of the advantages, when it is a matter of difficult lines, lies in the reduction in the engine weight for a given tractive effort. Unfortunately, however, in the present circumstances, the first cost of electric traction is still very high, and, except in special cases, constitutes a difficulty which may be termed insurmountable, in developing this mode of traction in secondary railways.

We have seen that the electrification of main lines is usually limited to the suburbs of large cities, to the highly deloped and rich industrial regions, and to mountainous regions, when the latter possess a considerable traffic or also when the ressources of water power are very great.

On secondary railways or railways of local interest, electrification has only extended in countries where the development of rural distributions of electricity for lighting and power enables the latter to be obtained under conditions which are particularly favourable. This development (which moreover has not been effected outside Europe except in the United States and Japan), closely linked up with the economic production of current, constitutes the threshold to be passed before the electrification of secondary lines can be made possible, which electrification in its turn may have a favourable effect on the production and distribution of electrical energy, as may be seen in Morocco, with regard at present to the main lines.

As regards the colonial railways, it will be readily understood that the question of their electrification has not even arisen, if the different stages of transformation which colonial railways are in general undergoing are followed. Laid down in the first place with the character of light railways, and often with inferior material, a start is made, when it is necessary to meet the growth of traffic, if possible with the rectification of the line, the strengthening of bridges and rails, the acquisition of heavier rolling stock, and if need be, the widening of the gauge. This is what we have seen in Nigeria, Rhodesia, the Congo, etc.

The lack of coal and the poor quality of the feed water may induce some colonial lines of main line character, to consider electrification; but this has only occurred in countries possessing sources of hydro-electric power already being exploited. The difficulty and the expense of distribution, coupled with the generally low current consumption and the high first cost of electric traction, make it very improbable that electrification will be extended to the secondary colonial lines. The latter, like most of the main lines, merely confine themselves to using special methods of traction when the features of the line or of the traffic demand it.

In brief, in most countries, electrification is out of the question as regards secondary lines except for the new lines, notwithstanding the fact that a considerable saving might be effected, either in reducing costs of labour, energy and repairs, or again in the reliability and efficiency of modern electric plant (the automatic sub-stations and mercury vapour rectifiers employed for preference today contribute largely to economy in working). On the other hand and contrary to what might appear at first sight, secondary lines having an important goods traffic have least to gain by electrifying, because it is just this traffic which is able to cover its expenses, since the steam trains are put to the best use in this service; in addition, these lines are faced with the problem of dispensing with their old steam traction material and the superfluous employees.

If the passenger traffic is important, as occurs with secondary railways serving populated regions or connecting up cities of any importance, electrification may be necessary in order to ensure a frequent service with a reduction in the expenditure, provided always that electrical energy may be obtained under advantageous conditions; in these cases whether electric traction is used in place of steam traction, or is used on new lines, as is most frequently the case, the commonest system of electrification and without doubt the best, is that of moderate or high tension direct current (500 to 1 000 volts). This enables regional distribution networks to be employed, usually three phase at 50 or 60 cycles. The electrification of the main lines also forms an easy method of extending electric traction to the secondary lines, a principle which has been applied as we have seen on some American lines.

Most of the secondary lines, as regards passenger traffic, require a very frequent service of very light trains, and under these conditions electrification is undoubtedly the most economical solution.

The problem remains intact, however, and must be met, if it is considered that the passenger traffic offering these features is the basis on which many secondary lines are founded, and that the limitations imposed by a less frequent service, such as that which may be effected with steam traction, cause the traffic to drop so much that it is often necessary to consider the suspension of the line.

We have seen that, in the United States of America, where these problems mainly arise, half of the total traffic is concentrated on 10 % of the total length of the railways; there are in consequence a large number of lines with a small traffic, the operation of which constitutes a serious problem, aggravated in many cases by the fact that, as was said in Chapter I, it is often necessary to operate secondary railways, whether belonging to a system or isolated, notwithstanding the fact that they do not pay, but because they are useful to the country and to the development of outlying regions, and because they are often able to bring considerable traffic to the main lines; it is for this reason that the solution of the problem regarding the traction suitable for these railways is of great importance.

In the United States, the competition of road transport presents the proportions and very keen features mentioned in Chapter II; statistics also show that despite the enormous increase (about 300 %) in the total volume of business since the end of the European war, the total number of passengers using the railways is constantly diminishing. This deviation of traffic, appreciable to a greater or lesser extent in all civilised countries, will continue to increase, especially on secondary lines, if the railways are not equipped to meet this competition.

It is evident that steam traction is no longer able to attract the passengers of the secondary lines, some of which lines still continue to use as formerly, old stock, thus rejecting all idea of comfort and safety and inducing the passengers to use other more attractive means of transport.

On the other hand, as regards the economic aspect of steam traction on these lines, the main reason of the loss is that most of the steam locomotives in use on secondary lines were designed for a service differing from that to which they are applied; the total expenses of the train and the labour expenses do not correspond to the service effected, and for this reason the total costs are greater than the economic capacity of the line.

Electrification not being regarded as a remedy for this state of affairs, except in special cases, chiefly on account of the high cost of installing and maintaining the system of distribution (supply lines, sub-stations, contact line) it is absolutely necessary to make efforts to effect a saving in the operation of the passenger service by flexibly adapting the material to the traffic which it is desired to effect; the use of modern stock for the formation of light and frequent trains, that is to say, the rational utilisation of motor coach units, ought to enable the secondary lines not merely to support themselves but also to bring a remunerative traffic to the main lines.

Motor vehicles, of any type, adapt themselves perfectly to passenger transport on the economic lines, and that is the reason for their prosperous development and for the importance which their study and use acquires for secondary lines and even main lines, on which there does not appear to be any possibility of dispensing with steam traction for goods traffic.

The different types of motor coaches which are in use at present on secondary lines, or which might be used for light traffic on some main lines, may be considered in the following order, according to the importance of the services to be effected :

1. Petrol motor coaches, with direct transmission, 30 to 40 H. P., capacity 30 to 40 seats.

2. Steam motor coaches, with single or articulated units, the former capable of pulling one coach or not as the case may be, accommodating 70 to 150 passengers.

3. Electric accumulator motor coaches capable of pulling one or two trailer coaches, as the case may be, usually 100 to 150 H. P., and having a total capacity similar to the above types.

4. Gasoline-electric or oil-electric motor coaches, 100 to 300 H. P., very large seating accommodation and capable of pulling one or two coaches.

5. Oil-electric motor coaches (Diesel or semi-Diesel) very powerful (300 to 500 H. P.), capable of pulling three or four coaches, actually constituting light trains.

A rapid glance will be cast on the economic results obtained with the use of this material on secondary lines.

Petrol motor coaches. — Petrol motor coaches are frequently employed on railways of local interest, the traffic of which adapts itself perfectly to their features. Their use on a large scale is comparatively recent, seeing that before 1914 these railways had the monopoly for local transports to distances of any importance. These conditions, as we have seen, have undergone a radical change with the development of the motor car, motor omnibus services and the transport of goods by powerful motor lorries.

As regards a large number of these, imparting to their operation the required flexibility, has been to take advantage of the improvements in the internal combustion engine in order to adapt it to their services. The method of putting this idea into practice consists in combining the method of traction in question with that of steam traction, which remains as a skeleton of the system for the goods traffic; mixed steam trains, so frequent on lines of a secondary or local interest, ought to be entirely prohibited.

There are a fair number of different types of this sort of coach but they may be reduced to two main types : coaches of the motor omnibus type, and derived directly from the features of motor omnibuses, and motor coaches properly so called of the same type as railway coaches. The former generally possess accommodation for 20 passengers seated, 10 standing and 1 000 kgr. (2 200 lb.) of luggage; the latter can offer 40 places on the average, and according to the gradients, can pull one 10-ton coach with 40 places.

The motor bus type is somewhat cheaper as regards its first cost and running expenses, unless the railway type of coach has been obtained by converting a railway coach as is frequently the case.

The chief saving effected by using these coaches is in connection with the costs of labour, maintenance and repairs, and even those of water supply and the maintenance of the permanent way. The fuel consumption depends upon the engine power, and for this reason at least in Europe, the use is restricted to internal combustion engines of a power not exceeding 60 H. P. In point of fact, in spite of the efficiency of the explosion engine being 2.5 to 3 times that of the combined boiler and steam engine unit, the cost of fuel is, on the average in Europe (where the calorie of petrol is worth 10 times that of coal) double that of a steam engine of equal power. For this reason, and also because it cannot be run on a cheaper fuel, the petrol motor coach cannot be utilised except for very light and frequent traffic, as is suitable for some local railways and certain secondary railways, without there being any hope for the present of replacing steam traction entirely.

According to the information provided by a large number of railways, the total saving in the operating expenses, as compared with steam traction, vary from 20 to 80 % according to local conditions; in America, where fuel is cheaper and where on the other hand, labour is dearer, the saving is frequently of the order of 85 %.

Below a few recent data are given, comparing the cost per train-kilometre (per train-mile) with the two systems of traction on one of the French lines.

Cost of :		Steam traction		Petrol motor coaches			
				Railway type		Omnibus type	
		Per train-km.	Per train-mile.	Per train-km.	Per train-mile.	Per train-km.	Per train-mile.
Traction	Fuel	0.95 fr.	1.538 fr.	0.50 fr.	0.810 fr.	0.39fr.	0.631 fr.
	Oil.	0.05 —	0.081 —	0.05 —	0.081 —	0.04 —	0.065 —
Wages		0.50 —	0.810 —	0.23 —	0.372 —	0.23 —	0.372 —
Repairs		0.75 —	1.214 —	0.22 —	0.356 —	0.18 —	0.291 —
		2.25 fr.	3.642 fr.	1.00 fr.	1.619 fr.	0.84 fr.	1.359 fr.
Interest and depreciation				0.30 —	0.485.—	0.30 —	0.485 —
				1.30 fr.	2.094 fr.	1.14 fr.	1.844 fr.

The coal consumed is 9.5 kgr. per train-km. (33.7 lb. per train-mile) estimated at 100 fr. per ton; in the case of steam traction, three employees are required per train, and on motor coaches two, although actually one would be enough, as is the practice in many cases.

These coaches can make daily runs of 150 to 200 km. (93 and 124 lb.) [at speeds of 40 to 50 km. (25 to 31 miles) per hour] while that of steam locomotives does not exceed 100 km. (62 miles); the cost of the coach-kilometre increases with the power of the engine used, but not in proportion. Still more economical results may be expected if the popularity of this mode of traction leads to improvements in internal combustion engines, and if the distillation of wood and coal enables a cheaper fuel to be obtained.

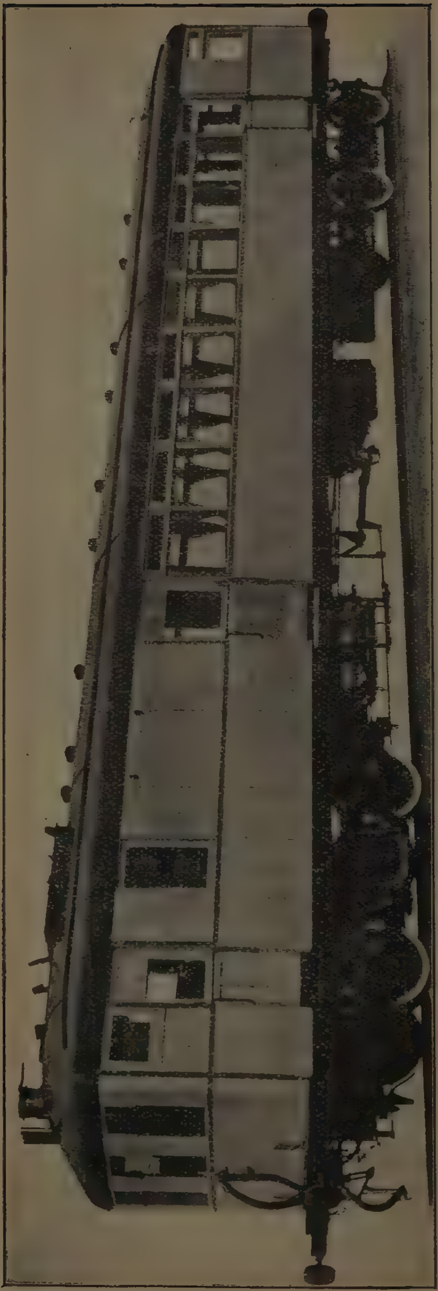
Fig. 9. — Steam motor coach of the London & North Eastern Railway.

Steam coaches. — When liquid fuel is scarce or when its price is prohibitive for economic operation, or when steam traction may be realised under satisfactory conditions owing to ready and cheap supplies of coal and water, very interesting results may be obtained by using steam motor coach units.

England is the country where this system of traction has been most developed, and consequently it is also met with in her Dominions and Colonies, where it is often used with interesting results.

The types of steam motor coaches may be reduced to two : single units, capable in most cases of pulling a coach, and articulated units, formed of two bodies mounted on three bogies.

The features of the boiler and steam engine have been improved recently with the object of obtaining a smaller specific consumption and a greater radius of action. The characteristics features dis-

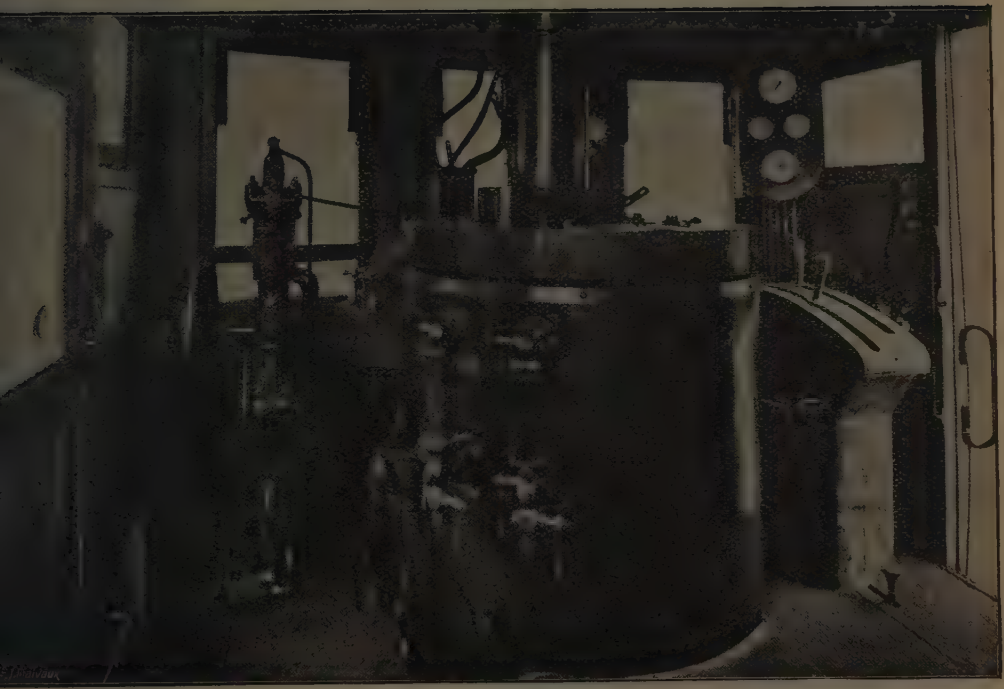

Fig. 10. — Steam motor coach of the London & North Eastern Railway. — Driver's cab.

tinguishing the new series of units that the London and North Eastern Railway has recently put into service are very remarkable.

These coaches have an accommodation of 59 passengers seated and 20 standing, and are provided in addition with a baggage van for 3 tons of luggage and two driver's cabs. The weight of these coaches empty is 30 tons.

The boiler of the « Sentinel » vertical type, works at a pressure of 21 kgr./cm² (300 lb. per sq. inch) and despite its low weight (1 054 kgr. = 2 320 lb.), has an hourly evaporating rate of 1 065 kgr. (2 350 lb.) with a superheating temperature of about 370° C. (695° F.).

The furnace has been designed for burning coal, but alcohol or mazout may be burnt with the same evaporating power (the consumption of mazout would be 1 lb. per 10 lb. of steam).

The water tank and coal box have a capacity of 1 430 and 1 520 kgr. (315 British gallons and 3 350 lb.), respectively, permitting a run of 96.5 km. (60 miles) without replenishing the water (which moreover may be taken up while running) and 480 km. (300 miles) without replenishing the fuel.

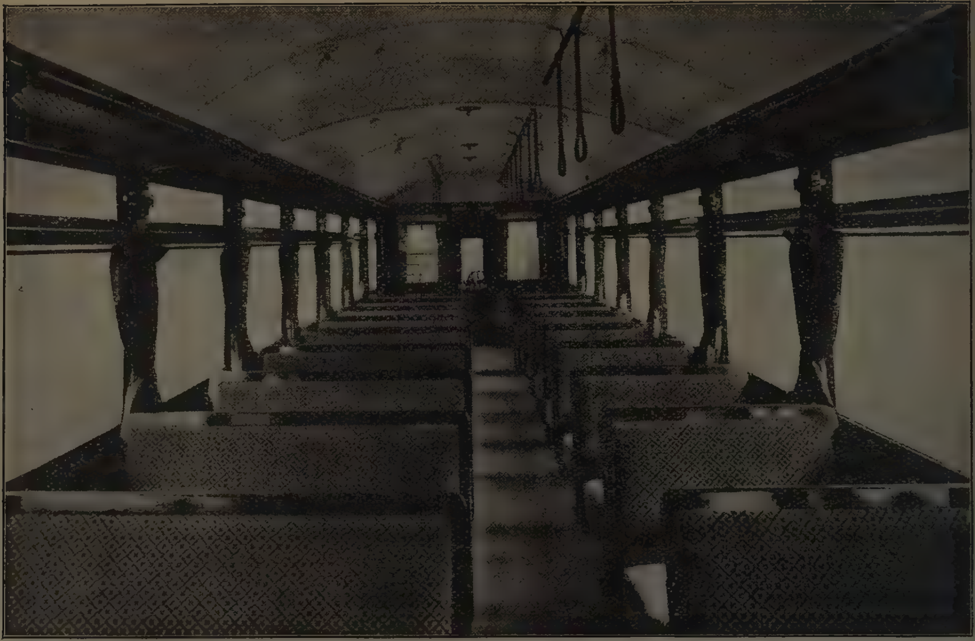

Fig. 11. — Steam motor coach of the London & North Eastern Railway. — Interior of saloon.

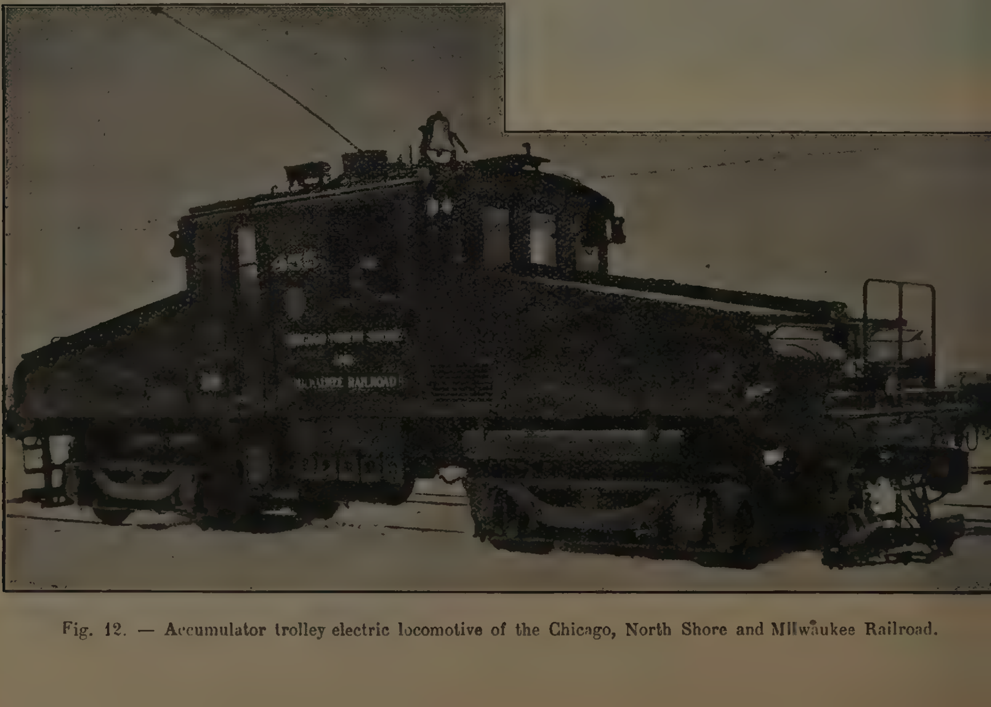

Fig. 12. — Accumulator trolley electric locomotive of the Chicago, North Shore and Milwaukee Railroad.

The engine rated at 130 H. P., is placed under the coach and occupies very little space (2.090 × 1.245 m. = 6 ft. 10 3/8 in. × 4 ft. 1 in.); it is single acting, of a type resembling the internal combustion engine, and consists of six horizontal cylinders in line engaging the driving axle through a cardan shaft at each end and two pairs of gearwheels mounted directly on the shaft. The average working speed is 450 revolutions per minute.

Its maximum speed on the level is 90 km./h. (56 miles); one of the features of this coach is the entire freedom from vibration at all speeds. The maximum tractive force at the wheel tread is 1 240 kgr. (2 730 lb.) which corresponds to a starting acceleration of 35 to 50 cm./sec. (13 3/4 to 19 11/16 inches per second) according to the load.

The coal consumption is 7.25 to 8 kgr. (16 to 17.5 lb.) per horse power-hour with an admission of 40 %.

Generally, the coal consumption in the single units is of the order of 2.5 to 3 kgr. of coal per km. (8.9 to 10.5 lb. per mile); the working costs, including upkeep, wages, depreciation of capital, and fuel are of the order of 2.50 fr. (French) per km. (4 French francs per mile) and differ by 40 to 50 % from those corresponding to light trains pulled by locomotives. It will be seen therefore that the steam motor coach may be put to very interesting use, not merely on railways of local interest, but also on the secondary lines of the main railways; the comfort, speed and regularity of running of these new high power and high capacity motor coaches are much greater than those which the rail motor cars are able to offer, and will eventually be able to protect these lines from all competition.

Electric accumulator motor coaches. — It has already been seen that the petrol engine of a power greater than 60 H. P. is costly in consumption (1/2 litre per km. [0.177 Brit. gallon per mile] must be reckoned on as an average) and that, in addition, direct transmission for powers greater than this has not been investigated. On secondary railways powers of 80 to 100 horse will be frequently required, in which case and provided electrical energy is available in economic conditions, especially at certain times of the day, electric accumulator motor coaches may find a justifiable application.

The technical and economic difficulties relating to the construction and maintenance of batteries intended for traction service, have had as their result that up to the present traction by accumulators has not been very extensive. These difficulties are gradually being removed, however; in France, Germany and Italy, accumulators are being used successfully in light coaches for secondary lines and in America this system is likewise extending for equipping large shunting locomotives.

In France, the « Compagnie des chemins de fer économiques des Charentes » (acting under the protection of the act of 13 August 1920, granting subsidies for the electrification of this type of railway), has put on trial on its lines 6 accumulator motor coaches, with the object of reducing working expenses and of regaining traffic which has been lost owing to competition by motor vehicles.

The coaches have a seating accommodation for 32 passengers with luggage. Their weight is 14 tons and they can in addition pull one or two 5-ton trailer coaches. The hourly output is 108 H. P. distributed over two motors mounted on the same bogie. Its radius of action is 150 km. (93.2 miles) (without recharging the battery) and its speed is 47 km. (29.2 miles) per hour on the level.

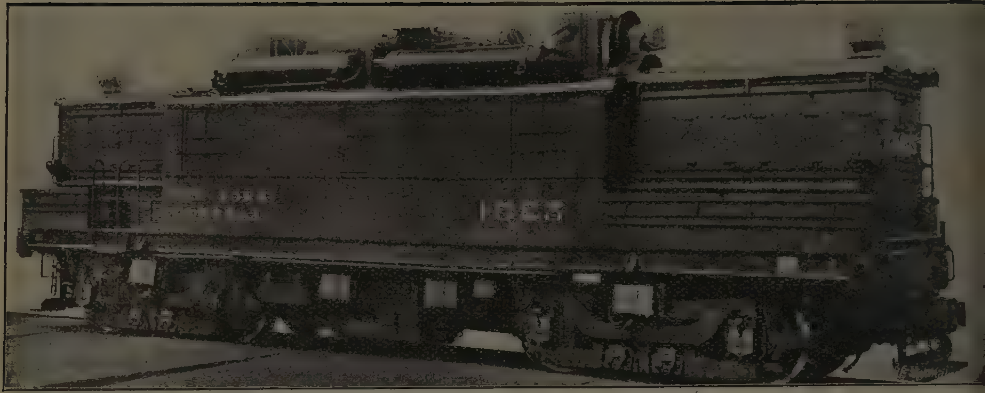

Fig. 13. — Diesel-electric accumulator locomotive of the New York Central Railroad.

The battery is composed of 180 iron-nickel cells in series, with a total weight of 8.5 tons, *i. e.* 48 kgr. (106 lb.) per cell, including the electrolyte; its discharge capacity is 750 ampere-hours in 3 hours 45 minutes and the discharge current is 300 amperes for 15 minutes and 400 amperes for one minute, on starting. The voltage per cell varies from 1.4 to 1, the mean voltage being 1.2.

The traction motors are excited by means of two dynamos, and have the characteristics similar to those of series motors; starting is effected by means of resistances. The motors may also function with regeneration, which, besides braking the train, charges up the battery, and results in appreciable saving in the consumption of current. According to the trials made on one Italian line, the saving may attain 27 % of the total consumption, depending of course upon the gradients on the line.

The charging stations are three in number, equipped with mercury vapour rectifiers; the average efficiency of these stations is 0.87 and of the battery 0.45.

The observed costs per motor coach-km. (per motor coach-mile) are as shown below :

	French francs	
	Per km.	Per mile.
Electrical energy	0.50	0.810
Maintenance of batteries . .	0.40	0.648
— of coaches. . .	0.20	0.324
— of charging stations. . . .	0.10	0.162
Drivers	0.40	0.648
Total. . .	1.60	2.592

At the present price of coal, the cost of a steam train of a similar capacity is, on the line in question, 3.20 fr. per train-km. (5.181 fr. per train-mile).

Energy costs 0.16 fr. per kw.-h. at the charging stations, which is very low (generally, if recourse has to be had to the production of energy by steam, the price would not be less than 0.27 fr.) since it a matter of night supply. It is in just this facility that a major part of the saving of this system of traction is to be found.

The problem of maintaining the batteries is of equally great importance; the manufacturers guarantee as a rule to do this for an annual sum of 12 % of the cost price for moderate runs (50 to 100 km. [31 to 62 miles] daily), which sum increases with the daily run of the motor coach.

The purchase price is 350 000 fr. for the coach of the above-mentioned line; for heavier coaches, it attains 500 000 fr. or more, but the depreciation, always high, then increases the cost of a coach-kilometre disproportionately.

This constitutes one of the reasons, which for the present at least, make the possibility of employing this system on goods locomotives for secondary railways very remote. In America, however, it is generally used for shunting locomotives, in very powerful units, with which a considerable saving is effected over the cost of steam traction by taking advantage of the low price for the supply of energy.

The Chicago, North Shore & Milwaukee Railroad has recently put into service several accumulator locomotives for the goods service in various industrial centres situated along its line. The weight of these locomotives is 65 tons and they may work with a trolley (the battery being charged up at the same time) or without it, so as to be able to run on lines where there is no overhead line. The battery is the Exide-Ironclad type, composed of 192 cells, and is charged by means of a motor generator set acting automatically.. The neutral point is connected to earth, giving 225 volts for the half battery, and its capacity is 600 ampere-hours, being able to obtain 260 kw.-h. with one charge. The locomotive is provided with four 205-H. P. motors.

The New York Central Railroad also employs 4-axle locomotives, provided with a battery for shunting on its lines which are not electrified. These locomotives weigh 115 tons, and can develop a tractive effort of 15 400 kgr. (33 950 lb.); they are equipped with four motors giving 415 H. P. per hour at 600 volts. The battery is the Exide-Ironclad type, comprising 218 cells, and its capacity is 680 ampere-hours for a period of 6 hours, *i. e.* 294 kw.-h. at 432 volts.

For the purpose of charging the battery, the locomotive is fitted with a Diesel oil engine, of 300 H. P., six vertical cylinders, with solid injection and constant speed, coupled to a 200 kw. generator; during the overcharge period, the charge is distributed between the generator and the battery. The battery provides sufficient energy for a run of 8 hours without requiring recharging. Its weight is 15 tons, that of the engine is 16 tons and of the motor-generator set is 13 tons. The speed of the locomotive (which is provided in addition with collector shoes for taking current from a third rail) is 13 km. (8.1 miles) per hour when running on the battery, and 29 km. (18 miles) when running on external energy.

One of the most powerful locomotives at present in service, is that which has been built for shunting on the Chicago & North Western Railway; it weighs 118 tons and is capable of pulling a 1 700-ton train. The battery can supply 2 700 ampere-hours in six hours, with a maximum discharge of 6 500 amperes. It comprises 120 cells and weighs 36 tons, one charge being sufficient for eight hours, in spite of which the locomotive is provided with a 200-H. P. petrol engine producing a supplementary charge when the length of run exceeds this time. With one charge the locomotive can pull a 2 000-ton train for a distance of 26 km. (16.2 miles) at a speed of 20 km. (12.4 miles) per hour.

The average speed used in service is 8.7 km. (5.4 miles) per hour with a daily run (in eight hours) of 42 km. (26.1 miles), requiring a consumption of 0.37 ton of coal per km. (0.6 ton of coal per mile); the average cost of energy is 4.7 cents per km. (7.6 cents per mile) at the rate of 1 cent the kw.-h., the battery being charges up at special times (*off-peak*). The average train is 425 tons and the average shunting distance is 192 m. (630 feet).

The possibilities which this mode of traction is able to afford, provided electrical energy is available under economic conditions at special times, will thus be understood.

Gasoline-electric or oil-electric motor coaches. — The obstacles which, owing to the high price of fuel, are placed in the way of the development of powerful petrol engines in Europe do not exist in America, where motor spirit may be had at exceptionnally low prices. The use of motor coach units provided with petrol or paraffin engines, generally of 150 to 300 H.P., is very widespread, enabling them to be used on secondary lines with a traffic much greater than would be possible with the petrol coaches which have been considered above.

These units vary greatly in type, and in certain cases attempts are still made to effect economies, as we have already had the occasion to see, by using distilled products that are cheaper than spirit or petrol, the latter being used exclusively for starting up. Electric transmission is general for high power internal combustion engines, owing to its simplicity, regularity and high efficiency. These have led to the improved gas-electric equipments which are to be found in use today, as regards both rail

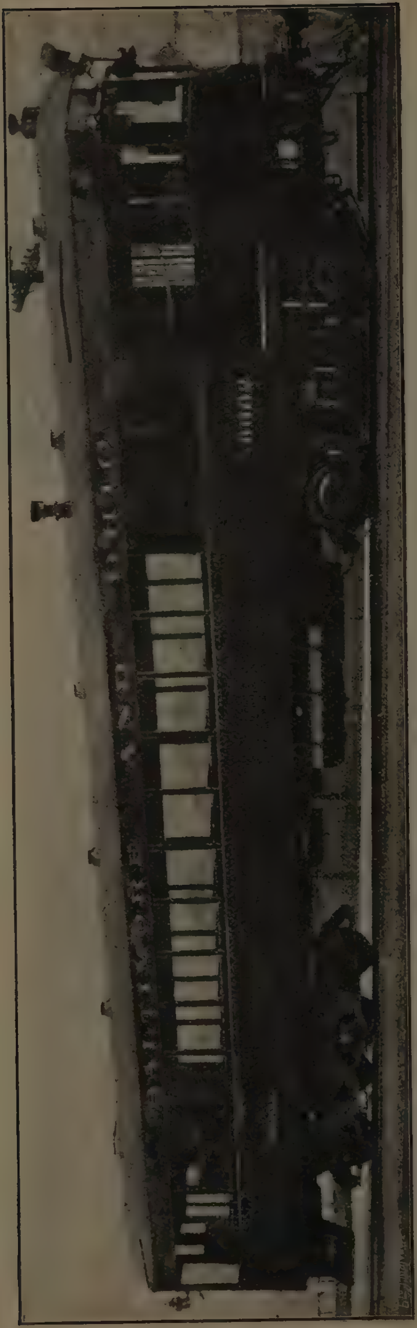

Fig. 14. — Gas-electric motor coach of the Baltimore & Ohio Railroad.

motor coaches and the high capacity motor omnibus.

By the use of this material, which, as already mentioned, is employed in America and other countries, not merely to effect a saving in the operation of secondary lines having a light traffic, but also for stimulating and recovering the passenger traffic, the expenses per train-kilometre obtained are approximately 30 to 40 % (depending upon the circumstances) of those of steam trains giving a service which is identical. The price of these units varies between $17 000 and $40 000 according to the type and capacity. In addition, they possess the advantage over other systems of being able to be driven as multiple units from either end of the train, in conformity with the current practice in electrical equipment with external supply of power.

In the table below are given the cost of traction on one American line 65 km. (40.4 miles) long, for a gas-electric train (composed of one motor coach for passengers and luggage and one trailer coach for passengers) and for a steam train (composed of one locomotive, tender, a mixed coach of passengers and van and a passenger coach), both having the same accommodation :

	Gas-electric. Dollars.	Steam. Dollars.
Fuel (coal or petrol)	338.20	603.00
Lubricants	17.11	35.00
Water	—	10.00
Cleaning	56.52	35.00
Fittings	6.86	35.00
Driver	297.72	297.72
Guard	288.56	288.56
Train employee	214.54	453.46
Stoker	—	220.30
Depot expenses	46.87	101.00
Total	1 476.74	3 045.04
Cost per passenger-km.	0.75 cent	1.54 cents
(per passenger-mile)	(1.24 cents)	(2.49 cents)
Cost per train km.	37.14 cents	76.40 cents
(per train-mile)	(60.13 cents)	(1.24 dollars)

The result is a monthly saving of $1 568, *i. e.* $18 816 per annum, or approximately 31 % of the cost of the motor coach and trail coach (without deduction of the present value of the steam material).

On other railways of a greater traffic, the cost of the train-kilometre is reduced from 57 to 38 cents, that is to say, a gas-electric train, costing $60 000 with a daily service of 161 train-tr.-km. (100 train-miles) per day, produced a saving of $25 500 per annum, or 43 % of the capital invested.

The same economies are likewise obtained with a still heavier traffic, requiring the use of multiple coupled units. Below is given the information relating to an interurban line 205 km. (127.4 miles) in length with suburban sections of 65 km. (40.4 miles) in each of the cities served (United States of America).

The steam service requires the use of 6 *Pacific* locomotives on the main line, 16 locomotives for the local services and 75 passenger coaches, with a present value of $275 000 for all this stock.

To ensure the service with gas-electric equipment, it is necessary to use 37 motor coaches, each worth $39 500, and 37 trailer coaches converted from the steam traction : the cost of this conversion is $2 500 per coach; the total value of this stock is $1 554 000 and assuming a present value of $238 000 for the locomotives and coaches in excess of the steam traction, the necessary capital is $1 316 000.

The annual costs and the costs per tr.-km. (per train-mile) are as given below :

	Gas-electric			Steam		
	Per train-kilometre. Cents.	Per train-mile. Cents.	Per annum. Dollars.	Per train-kilometre. Cents.	Per train-mile. Cents.	Per annum. Dollars.
Wages	19.65	31.81	230 557	24.10	39.01	282 720
Fuel	11.93	19.31	139 859	15.00	24.28	175 113
Repairs, engine stock	3.77	6.10	44 227	18.55	30.03	217 610
Lubrication	1.12	1.81	13 151	1.05	1.70	12 359
Depot expenses	1.51	2.44	17 692	4.80	7.77	56 419
Maintenance of coaches	1.72	2.78	20 172	5.00	8.10	58 616
	39.70	64.25	465 658	68.50	110.89	802 837
Cost of shunting			18 650			55 900
			484 308			858 737

Whence :

	Gas-electric. Dollars.	Steam. Dollars.
Capital to be expended	1 316 000	—
Annual operating costs	484 308	858 737
Fixed charges (interest, depreciation, insurance)	170 477	132 217
Total operating expenses	654 785	990 954
Saving effected	336 169	—

As a percentage of net capital 25.6 %.
As a percentage without fixed charges 28.5 %.

It should be noted that the chief saving is always obtained on the fuel, repairs and wages; in the case in question, the remarkable saving effected on the repairs is due to the use of locomotives that are now very old, which is very frequent on most of these railways.

Diesel-electric motor coaches. — The use of Diesel engines is almost in its infancy as regards railway traction, since so far all activities have been directed for preference in improving steam or electric locomotives.

Internal combustion engines, and those of the Diesel type in particular, which produce energy cheaply with all kinds of fuel, have recently attracted attention as regards their application to the traction of trains; gear transmission and hydraulic transmission having been abandoned, mainly because of their complicated nature, in preference to the production of electrical energy in the coaches themselves, which constitutes a means of partial electrification with all the advantages accruing from the elimination of power stations and contact lines, enables the utmost advantage to be taken of the power of the Diesel engine, and improves the driving of the coaches and the efficiency of the system.

Except in special cases, some of which have already been mentioned, the service to which this type of internal combustion engine unit is generally applicable, is that of secondary railways or of sections of main lines where the traffic is light and where a small number of trains of a comparatively high tonnage or again of frequent and low capacity trains suffice to meet all requirements.

The motor coach, of any type whatsoever, was introduced on secondary lines in order to avoid expenses and to obtain a more frequent service than that supplied by the usual steam trains. Where petrol motor coaches are insufficient and where the use of steam motor coaches fails owing to the necessity (as on the locomotive) for two employees to drive it, a saving in personnel may be effected at the same time as in fuel, by making use of internal combustion engines, whether it is a question of the gas-electric equipments, already considered, for rather light traffic or for countries where the use of spirit or petrol is economical, or again of oil-electric equipments of the Diesel or semi-Diesel type, if this factor does not exist or if a greater power is required.

The general use of the Diesel engine, however, remains subject to the condition that mineral oil can be obtained under satisfactory conditions, which is not the case in every country; the tests carried out with other fuels, as well as the investigations in progress on the hydrogenation of coal, and the gasification of mineral and vegetable fuels, etc., lead one to expect that the use of this type of engine will be extended to the countries commanding these resources.

As regards their advantages over steam traction, they are undoubtedly of considerable interest : their thermal efficiency is five times that of the steam locomotive, the fuel consumption is less, the expenses of the personnel are smaller, as is likewise the housing of the stock, fuelling and driving are simpler, and the runs are longer.

The report for 1928 of the Committee appointed by the American Electric Railway Association for studying the subject of « Branch line electrification and self-propelled cars » contains some interesting information on the use of Diesel-electric motor coaches.

The fuel consumption is 1 litre per 100 tonne-kilometres (0.36 British gallon per Engl. ton-mile) or on the average, 5.2 l. per km. (1.84 Brit. gallons per mile) the trains hauled varying from 55 tons (one unit) to 136 tons, and the speed from 40 to 60 km. (25 to 37.3 miles) per hour.

The service is very good; breakdowns cause stoppages for 2 to 7 % of the total time only, half of this time corresponding to engine faillure alone, affected in an adverse manner undoubtedly by the lack of familiarity of the employees with the driving and repair of these units. The average run per breakdown or stoppage is 500 km. (310 miles), and the run per delay of 5 minutes due to these causes is 350 km. (218 miles), figures which are higher than the corresponding figures for coaches fitted with a petrol engine. The daily run attains 400 km. (250 miles), a distance which is surpassed in certain cases.

The repairs generally affect those parts that can be replaced gradually and without difficulty; the expensive overhauling, such as is required by steam engines being unnecessary. As regards the electrical portions, the results are equally good, which is today usual on electric railways; automatic control is frequently employed so as to avoid accidents due to errors in driving.

For the same number of seats, the expenses per kilometre, 25 to 38 cents (40 to 61.5 cents per mile), of a Diesel-electric train composed of one motor coach and one trailer coach, are at least half those corresponding to a steam train comprising a locomotive and two coaches; the saving is principally effected on the expenses for fuel, personnel and repairs.

Experiments recently carried out in Switzerland give the following comparative figures, per tonne-kilometre (per Engl. ton-mile) for the two systems of traction :

	Steam. Francs		Diesel-electric. Francs	
	Per tonne-km.	Per Engl. ton-mile.	Per tonne-km.	Per Engl. ton-mile.
Fuel	0.676	1.105	0.182	0.298
Lubrication	0.306	0.500	0.039	0.064
Personnel	0.392	0.640	0.196	0.320
Inspection	0.057	0.093	0.016	0.026
Repairs	0.016	0.026	0.023	0.037
Total.	1.177	1.924	0.456	0.745

that is to say, the expenses when using Diesel engines are 38 % of those corresponding to steam traction; in addition, general inspection or overhauling lasts 27 days for the motor coaches and 119 days for the steam locomotives.

The above information was based on a traffic of 6 200 000 t.-km. gross (3 791 000 Engl. ton-miles-gross) with Diesel electric motor coaches, the trains being made up, respectively, of steam locomotives of 24 to 30 tons in weight, pulling 390 or 500 tons and of Diesel-electric motor coaches, weighing 64 tons and 200 H. P., pulling 80 tons.

It should be pointed out that the considerable progress which is constantly being realised in internal combustion engines is continually modifying the above figures in favour of this system of traction, which as we have seen, extends in America to units and trains of large capacity. Similarly, in Europe, the London Midland & Scottish Railway has recently put into service a Diesel-electric train, made up of a motor coach fitted with a Beardmore-Diesel engine of 500 H. P. at 900 revolutions per minute, coupled to a 340-kw., 580-volt D. C. generator (supplying energy to two 280-H.P. traction motors), and three trailer coaches, with a total capacity of 300 passengers, capable of being driven from either of the two end cabs; the weight of the empty train is 144 tons.

Goods service on secondary railways. — As already pointed out, the conditions under which most of the secondary railways are being developed, cause it to be impossible in most cases, to dispense with steam locomotives for goods services; one of the biggest problems of this traffic, however, is the maintenance of the locomotives, and in many cases, the supply and distribution of coal and water.

When it is impossible to consider economically electrification, in countries like those of North America, where it is easy to obtain supplies of mineral oil under economic conditions, considerable advantages may be gained by employing Diesel-electric locomotives. Since 1926 their construction has been developed considerably, the types varying from that of 60 tons and 300 H. P. to those of 100 and 150 tons with a power greater than 1 000 H. P., capable of being coupled in multiple units, such as those recently constructed for various railways of the United States and Canada.

As regards the traction on secondary railways and shunting in the large stations, the type of 300 H. P. and 60 tons, already well-established in many uses, appears to be the most evident. The advantages of these locomotives over steam locomotives may be summed up :

1. They are capable of effecting a service of 24 hours for 6 days without interruption, providing about 7 000 hours per annum, while the steam locomotive can only provide 3 500 to 4 000 hours of service per annum.

2. The costs of maintenance and repair are half those of steam locomotives, estimated per hour or per tonne-kilometre.

3. The fuel expenses per hour of service or per tonne-kilometre are very much lower, depending upon the country (one quarter in America) than those corresponding to steam locomotives. In the United States, according to the statistics for one year, at 25 % of the capacity as mean load factor, the kw.-hour produced costs 1 cent for the type of locomotive in question, with oil for fuel at 5 cents per gallon, and lubricating expenses at 5 cents. The practical results always show that with Diesel-electric locomotives of low power, considerable tractive forces can be obtained for as low a consumption of fuel as for the most powerful units. As regards steam locomotives, the efficiency is, on the contrary, much less for the smaller units.

4. The maintenance expenses in the depots per locomotive-kilometre are 1/5 to 1/10 of those of steam locomotives.

5. This system of traction eliminates the water supplies and their maintenance, as well as coal stocks, handling of ashes, thus economising 9/10 of the rolling stock necessary for the transport of fuel.

6. In the depots, these locomotives occupy 5 times less room than steam locomotives of like power, and occupy 3 times less room in the repair shops.

7. The fuel consumption is nil when coasting and when standing, the con-

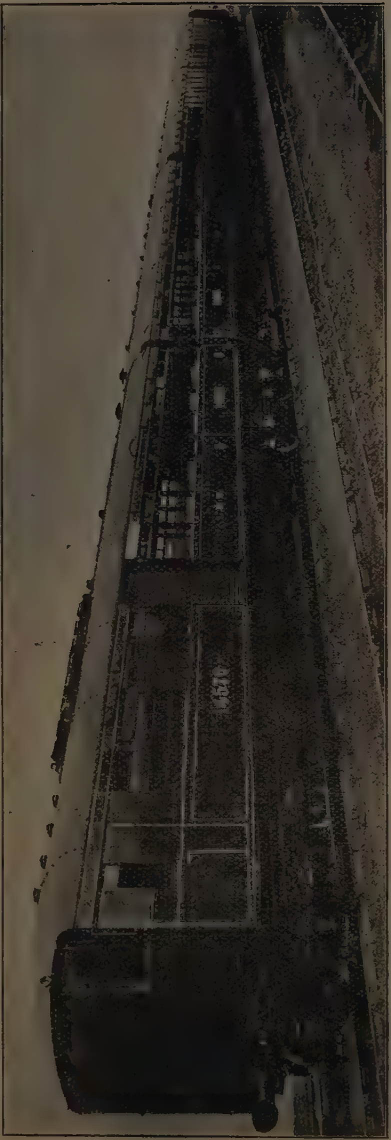

Fig. 15, — Diesel-electric train of the London Midland & Scottish Railway.

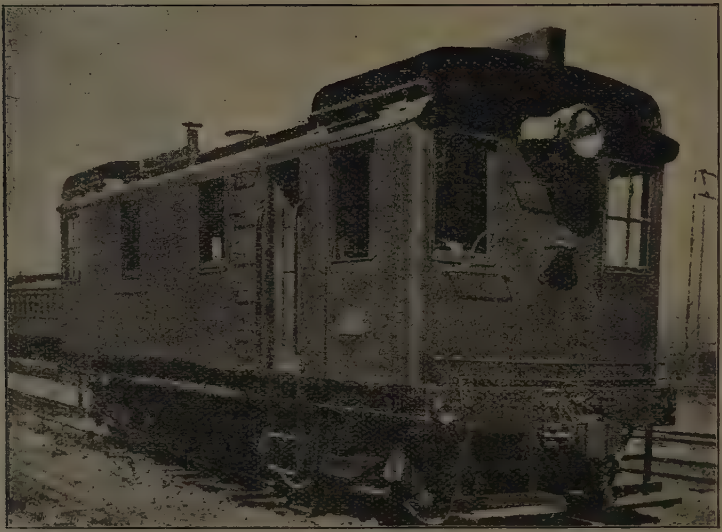

Fig. 16. — 60-ton, 300-H. P. Diesel-electric locomotive.

trary of what occurs in the case of steam locomotives.

8. There is very much less risk of fire, an important factor in some regions.

9. At low speeds (8 to 10 km. = 5 to 6.2 miles) the tractive force of these locomotives is double that of steam locomotives of equal power; consequently, they are able to render more service, especially in shunting operations.

10. They can run both on lines operated by steam and on electrified lines, and may be used in concurrence with one or the other system.

It must be admitted, however, that their cost is still very high, nearly two and a half times that of a steam locomotive of equal power. For this reason interest and depreciation expenses are also very high. Nevertheless, their use will generally give considerable economic advantages, the importance of which depends essentially on the cost of oil fuel in the country concerned.

CONCLUSIONS.

The examination of the predominant tendencies as regards the modification of the system of traction on secondary railways enables the following conclusions to be drawn :

1. « Complete » electrification of secondary lines, meaning by this expression the electrification of the driving stock, such as the construction of the system for the distribution and the external supply of energy, is only possible, in general, from an economic point of view, in countries or regions where electric energy is widely distributed, and

may be obtained under very advantageous conditions which favour the growth of the population and a corresponding increase in the traffic.

2. In the use of special systems for the service of certain traffic particularly that of passengers, « incomplete » electrification, that is to say, the electrification exclusively of the engine stock, either by the generation in that stock of the necessary electrical energy (Diesel-electric or gas-electric motor coaches) or by the accumulation of energy supplied by an external source (traction by accumulators) may be a solution for both secondary and main railways serving sparsely populated districts, or which are faced with the competition of other forms of transport, when the investment of considerable capital in « complete » electrification is not justified by the density of the passenger traffic or by the economies, which, taking all the factors into account, the substitution of electric traction for steam traction is able to effect, even for goods traffic.

Detailed Questionnaire relating to Question XIX : « Electrification of secondary railways ».

Definition. — By « secondary railways » should be understood those railways of which the normal or narrow gauge lines, while forming part of the general system, connect less important centres, and of which the characteristic features of engine stock, general construction, speeds and traffic are inferior to those of the main railways.

QUESTIONS.

A. — General.

1. — Do you operate, either directly or through an affiliated company, any secondary railway or railway of local interest ?

If not, state the secondary railways with which your lines are connected.

2. — Are your secondary lines operated in conjunction with, or independently of, the rest of the system ?

3. — In the last case, under what conditions of concession are the said lines operated ?

4. — Has the electrification of these lines been considered under the said conditions ?

5. — Is there any government order relating to electrification ?

6. — Situation of your secondary lines and features of the regions served.

7. — Connections with the main lines.

Connections with other secondary lines, tramways or omnibus services.

8. — Are you subjected to competition from parallel tramway or omnibus lines ?

9. Has electrification been :
investigated ?
introduced from the beginning ?

10. — In each case, what are the reasons which have prompted you to do it ?

11. — Present daily traffic : passengers — goods — special features.

12. — Will electrification result in an appreciable increase in the daily traffic ?

13. — Present composition of trains — number of passenger and goods trains — maximum gross loads.

14. — Personnel of the trains.

15. — Changes which electrification should bring about with respect to (13) and (14).

15. — General features of coaches and wagons used.

17. — Profile and plan of the line — minimum curves — maximum gradients, etc.

18. — Characteristics of the track : weight of rail — type and laying of rail — maximum allowable speeds — maximum per driving axle — wheel base — gauge.

B. — Steam traction.

19. — Steam locomotives or other tractors employed :

Number — main features — weight — brakes — dates and price of purchase.

20. — Present run made by these engines.

21. — Annual cost of steam or any other traction than electricity.

a) Fuel.

b) Train personnel.

c) Maintenance and repairs.
Personnel.
Material.

d) Lubrication.

e) Depreciation of the traction and rolling stock replaced.

f) Various.

22. — Number of locomotives in service, under repair.

23. — Cost of traction per tractor-mile or per tractor-kilometre.

24. — Cost per tonne-kilometre hauled in both directions of the line.

C. — Electric traction.

25. — System adopted for the electrification. Main features and the reasons justifying it.

26. — Production of electric energy. — Capacity. — Reserves.

27. — Supply network. Features.

28. — Price of the kilowatt-hour. Principles underlying the contract for the power supply.

29. — Sub-stations. — Number and distribution. — Characteristics of the sets. — Total capacity. — Reserve. — Protection. — Whether automatic. — Builder.

30. — Contact line. Type and features of the suspension. Supports and distance apart. Contact wires. Cables. Feeders. Sectioning. Suspension in tunnels. Contact line in stations : suspension and supply. Rail joints and lateral junctions. Return feeders. Pantographs or current collector : pressure, shoes (composition and life). Level crossings.

31. — Electric locomotives. — Number. — Types and builders. — Main features. — Power and tractive force corresponding to continuous running and for a run of one hour. — Number of motors. — Combinations and features of the latter (poles, brushes, temperature coefficients, shunting of induction fields, etc.). — Control : system, contactors. Auxiliary services appliances. Electric braking. — Protection. — Meters. — Lighting and heating. — Mechanical parts. — Trucks, frame, couplings, brakes.

32. — Motor coaches. — The same questions as for locomotives, with in addition number of places, and doors.

33. — Low tension lines of communication along the railway. The disturbances observed and methods employed for eliminating them.

34. — Signals and interlocking installations.

35. — Cost of electrification :

a) Sub-stations.

b) Contact lines.

c) Locomotives.

d) Motor coaches.

e) Supplementary works (buildings, lines, etc.).

35. — Annual cost of electric traction (actual or estimated).

a) Power consumption.

b) Sub-station :
Personnel.
Material.

c) Contact line :
Personnel.
Material.

d) Locomotives :
Train staff.
Maintenance and repairs.

Lubrication.
Annual run.
Cost per locomotive-mile or locomotive-kilometre.

e) Motor coaches :

Driver and conductor.
Maintenance and repairs.
Lubrication.
Annual run.
Cost per motor coach-mile or motor coach-kilometre.

f) Depreciation of works and material — delays — annual amount.

g) Various.

37. — Anticipated increase or reduction in the cost of electric traction.

38. — General ideas on :

a) Organisation for the erection and maintenance of the contact line.

b) Maintenance and repair of the electric tractors (periods for inspection and overhauling, runs made between the said periods, number of tractors under repair, etc.

39. — Auxiliary installations. — Fitting shops. — General description; personnel. Contracts with private firms.

40. — Photographs, graphs, drawings and regulations of any interest.

[656. 25]

REPORT No. 3

(Belgium, France and their Colonies)

ON THE QUESTION OF SIGNALLING OF LINES FOR FAST TRAFFIC AND IN MAIN STATIONS. DAYLIGHT SIGNALS. AUTOMATIC BLOCK SYSTEM (SUBJECT XI FOR DISCUSSION AT THE ELEVENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION) (¹),

By G. C. A. WILLAERT,

Principal Engineer, Permanent Way Department, Belgian National Railway Company.

Figs. 1 tot 3, p. 739

The signalling methods of the French and Belgian Systems were dealt with in detail in the reports presented at the London Session in 1925 by Mr. Laigle, Chief Engineer of the French Midi Railway, and Mr. de Benedetti, Chief Engineer of the Italian State Railways.

We have, therefore, only to make a complete summary of the question, i. e. to compare point by point the main characteristics of the signalling systems in use, and eventually to point out new methods and the evolution of ideas in regard to signalling since 1925.

We divide the subject into four chapters. The first is headed : Signalling of the line. It deals with the methods of signalling, the apparatus and the working of the apparatus.

In chapter II we study the protection of the trains by both the manual and the automatic block system.

A special chapter is reserved for daylight signals.

Lastly, the fourth chapter is confined to the signalling of main stations, and the centralisation of operation of points and signals.

CHAPTER I.

Signalling of the lines.

Before examining the characteristics of the signalling in use, we put the following question :

Are the methods of signalling the lines uniform throughout a system, or do these methods vary with the density and speed of the traffic ?

Let us examine from this view point the different French Railways.

On the *Paris-Lyons and Mediterranean Railway* the methods of signalling are uniform over the whole system, and are independent of the density and speed of the traffic. There is only one system of signalling and one set of rules.

It is the same on the *French Nord*, the *Paris-Orleans*, the *French State Railways*, and the *Alsace-Lorraine.*

On the *Midi Railway* the methods are uniform, with the exception of lines with heavy traffic, on which automatic block working is installed.

On the *Est Railway*, the methods are uniform, but the degree of application of

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(¹) Translated from the French.

these methods takes into account the speed and density of the traffic.

Speed affects the rules for spacing the distant signals; there are two limits for stopping distances; one for lines where the authorised speed is equal to or more than 100 km. (62 miles); the other for lines where the authorised speed is at most equal to 90 km. (56 miles) per hour.

The density of the traffic affects the arrangements for spacing the trains.

The signalling of secondary lines is usually confined to the signals necessary for the protection of obstructions, and to cover trains at rest. The spacing of the trains on these lines is assured by the same signals, which are held at danger for a specified time after the passage of the trains (or until receipt of a communication from the station ahead, when there is a block section from station to station).

On lines of a certain importance the spacing of the trains is assured by means of the block system, the signalling of which is superimposed on that serving to protect the stations.

The *Belgian National Railway Company* utilises for lines with dense traffic a system of signalling capable of giving four indications to the driver.

1. Stop (red at night).

2. Proceed and stop at signal ahead (yellow at night).

3. Proceed and slow down at signal ahead (orange-green at night).

4. Line clear (green at night).

For secondary lines, the signals can only give three indications :

Stop. — Proceed : Stop at signal ahead. — Line clear.

In neither of these two methods of signalling does the speed affect the rules of spacing the distant signals.

On the other hand, the same absolute block system and signal at danger rules the spacing of the trains on both the main and secondary lines.

§ 2. — *How are the signals spaced in relation to the point to be protected ?*

Is the distance which separates the distant signal from the next signal uniform, or does it vary with the speed of the traffic, the profile of the line, the method of braking, and the load of the trains ?

Interest in this question is such that we think it advantageous to reproduce in extenso the text of the replies which have reached us.

French Est.

The definite stop signal, unless otherwise prevented, is placed at least 100 m. (328 feet) in front of the point to be protected.

The distant signal covering the stop signal is placed at the full stopping distance from it. This distance varies with the speed of the traffic and the profile of the line.

The spacing may, however, be reduced if the distant signal is compulsorily approached at reduced speed by the trains to which it applies (for instance, just before a definite stopping point, or within a reduced speed area).

French Nord.

The square signal is located at 120 m. (394 feet) from the point it protects (facing point or crossover).

The green and white chessboard indicator announcing the square signal is placed 800 m. (2 624 feet) in front of that signal (¹).

The approach board of the semaphore signal is usually placed at least 800 m. (2 624 feet) therefrom (¹).

The red disc is placed 1 200 m. (3 936 feet) (¹) away from the regular stopping point in the station and at 800 m. (2 624 feet) from the first crossover (¹).

In front of stations where there is a semaphore, the red disc covers the shunting, and the approach board only repeats the semaphore. In such cases, the two signals are generally side by side.

All signals are located after enquiry on the spot, to determine their placing according to the local conditions of visibility and traffic.

Paris-Lyons & Mediterranean Railway.

The red and green discs are placed at the « specified distance » (Article 61 of the General Rules) from the spot from which the stop may be required.

The square boards and semaphores are placed some metres in front of the spot which they protect. However, squares protecting turnouts comprising converging roads, or a scissors crossing, are 100 m. (328 feet) at least from the face of the turnout or the danger spot.

In regard to braking regulations, which take into account the load of the train and the method of braking, the « specified distance » varies with the profile of the line and the maximum speed of the trains.

The speed limitations, whether they are attained or not in the area, apply to trains equipped with continuous brakes. They are reduced to one-half (without, however, going below 20 km. (12.4 miles) unless specially prescribed) for trains not equipped with a continuous brake, and for light engines.

Alsace-Lorraine Railways.

The main signal is located at 100 to 150 m. (328 to 492 feet) from the danger spot.

The distance which separates the distant from the main signal only varies with the speed of the traffic and the profile of the line, minimum 400 m. (1 312 feet, maximum 1 000 m. (3 280 feet).

French State Railways.

The absolute stop signals are usually placed at 50 to 120 m. (164 to 393 feet) from the spot to be protected.

The distance of the distant signal from the relative stopping points depends on the profile of the line between these two locations. It varies usually between 800 and 1 000 m. (2 624 and 3 280 feet).

Midi Railway.

The stopping distance (distance separating the disc from its covering post, distance between the absolute stop signal and its advance signal) is governed solely by the average profile between the disc or the annunciator on the one hand, and the point protected or the absolute stop signal on the other hand. When this latter exists, its distance in relation to the point to be covered varies according to local conditions and the position of the points

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(¹) When the falling gradient is equal to or more than 1 in 250, the spacings are respectively 900 m. (2 952 feet) instead of 800 m. and 1 300 m. (4264 feet) instead of 1 200 m.

which the signal has to protect. It is 1 000 m. (3 280 feet) if the average profile shows a rise of at least 1 in 200; on the level or falling it is 800 m. (2 624 feet) if the gradient is between 1 in 167 and 1 in 67; if the gradient is more than 1 in 67, it is 600 m. (1 968 feet).

Paris-Orleans Railway.

The distant « square » is everywhere placed normally at 1 000 m. (3 280 feet) from the spot to be covered. Our regulations provide that this distance may be reduced down to 600 m. (1 968 feet) on condition :

a) That there is 1 000 m. (3 280 feet) at least between the spot to be covered and the extreme point of visibility of the signal.

b) That, in foggy weather, the signal is preceded at 500 m. (1 640 feet) by a green slow-down light, but this rule is not in force on fast lines, where the protection must be effective at 1 000 m. (3 280 feet). However, on all lines, the square may be placed at a distance comprised between 600 and 1 000 m. (1 968 and 3 280 feet), when it is repeated by a green and white chessboard located 1 000 metres at least from the point to be covered.

We have submitted to the Chief Administration proposals for reducing the covering distance on rising gradients, but these proposals are still being studied by the Ministry of Public Works.

State Railways' Algerian Lines.

The distance which separates the distant signal from the next signal or the point to be covered, varies from 1 000 to 2 000 m. (3 280 to 6 560 feet) according to the profile of the line and the conditions of visibility.

Belgian National Railway Company.

The absolute stop signal covering a danger spot is placed at 50 to 60 metres in front of the danger spot, when the signal applies to running trains. It may be placed near the danger spot if it applies to trains held up or moving slowly.

The stop signal is preceded, at a distance of 800 m. (2 624 feet) from the stopping point, by a repeating signal, which may be passed. This distance of 800 metres may be reduced to 600 m. (1 968 feet) on an up grade, and extended to 1 000 m. (3 280 feet) on a down grade.

§ 3. — *How is the route indicated to the driver? Is it given by the signal near by and by the distant signal covering the dangerous point, by one of these two signals only, or by indicators independent of the covering signals?*

The French Est places in front of and at a short distance from the facing point, a signal giving a geographical indication of the route. It comprises as many horizontal arms as there are routes to be given. The inclined position of one of these arms indicates the route given. At night, this signal gives also a speed indication. The inclined arm presents a green or white light according to whether the point should or should not be crossed at reduced speed.

A distant route-indication is not given except in a very few cases where, by way of experiment, special signals for this purpose have been installed, but in the opinion of the Company, this arrangement is unlikely to be extended, as the utility of route indication, particularly at a distance, is being more and more contested.

But independently of the geographical indication of the route, the driver is informed by distinction signals of the limits of speed to be observed according to the position of the facing points.

With the *Nord Company* the methods are not different. The geographical indication of the route is given by a signal near to the points and distinct from the absolute stop signal. The indication of direction is given at a distance to a certain extent by « caution » signals. Thus, *on direct roads into stations*, indication of deviation is given by a green « caution » disc, showing a green light at night when it faces the road; the signal is turned sideways when the direct road is given, and faces the road when the train is to run into a siding or shed.

If the train is to be turned aside, the chessboard indicator is turned in the facing or « closed » position.

In *Alsace-Lorraine* it is the covering signal next to the absolute stop which itself indicates the route. This indication is not always complete from the geographical point of view; it shows either a straight through road, or a road branching to the left and one to the right.

The distant covering signal (which may be always passed) gives also an indication of direction, viz. it shows that the route to be followed is or is not off the main line.

With the *Belgian National Railway Company*, as in Alsace-Lorraine, it is the covering signals (nearby and distant) which indicate the direction; however, the adjacent signal gives as many indications as there are accessible roads. (The semaphore arms are either carried on separate posts arranged on a common gantry, or are linked up with numbers, which are illuminated at night. When the signal clears, a number appears indicating the road to which it applies).

In conclusion, in spite of the diversity of the arrangements adopted, there is unanimity of opinion as to the necessity of giving more or less completely the indication of direction by an adjacent signal (distant or not from the covering signal).

Certain lines inform the drivers at a distance, of the speed restrictions to be observed; others of the direction — deviating or not — of the road to be followed.

§ 4. — *Do the signals give speed indications to the driver? If so, how?*

On the Alsace-Lorraine System, the signals do not indicate the speed. However, a signal indicating a deviation imposes in principle a speed reduction to 45 km. (28 miles) per hour for passenger trains, 30 km. (18.6 miles) per hour for goods trains.

On the other French lines speed indications are given either by a « caution » signal or by « caution » boards.

The « caution » signal (green disc) requires in its « closed » position a reduction of speed to 30 km. (18.6 miles) per hour for passenger trains, and to 15 km. (9.3 miles) per hour for goods trains.

For speed limitations other than 30/15 km., boards are used having the maximum authorised speed in black figures on a white buchground.

On the *Belgian National Railway Company*, signals covering dangerous points do not give speed indications. On the other hand, there is no « caution » signal properly so called. The speed, when it should be less than the normal authorised maximum, is given by a triangular board indicating in figures the authorised speed.

To recapitulate, the speed indications

are given in principle in three different ways :

1. By a « caution » signal, which when closed requires speed to be reduced to the uniform limit fixed by the regulations.

2. By the covering signals even at turnouts : signals indicating a deviation impose a reduction of speed uniformly fixed by the regulations.

3. By boards, indicating in figures the maximum authorised speed.

§ 5. — *Do the signals governing block sections have the same form as those protecting dangerous points ?*

On the *Paris-Orleans*, where the block is absolute except on sections equipped with automatic block, the block signal is distinct in form from the signal covering a dangerous point. It is composed of a semaphore arm, but in certain stations the square signals do duty as block signals.

On the *Paris-Lyons-Mediterranean* the block signals which are semaphores have the same shape as those covering dangerous points but there is another signal for protecting dangerous points, viz. the square. This latter signal is never used as a block signal.

On the *Est Railway* the permissive block signals are always semaphores, whilst signals covering obstructions are either squares or discs.

In a small number of special applications, where an absolute block is desired (protection of underground lines, running through main stations, etc.) the square is employed as a block signal.

On the *French State Railways* absolute block sections are covered either by semaphores, or by squares : in the automatic permissive block the signals are light signals : in the non-automatic permissive the signals are squares, repeated by boards having the word « attention ».

On the *Nord Company* where the block is permissive, the block signal is a semaphore; the stop signals covering danger spots have a square aspect.

On the *Alsace-Lorraine* and on the *Belgian National Railway Company*, where the absolute block is in use, the block signals do not differ from those covering danger points.

CONCLUSION. — In the interests of simplicity it seems desirable to use, for absolute block, signals of the same form to govern the block sections and for protecting danger spots.

§ 6. — All the French Lines employ, during the day, besides light signals, either movable discs which are effaced for « line clear », or semaphore arms which take an inclined position for line clear.

All these signals are satisfactory. It is somewhat surprising to find nowhere any complaint about the insufficiency of the disc signal, which in the daytime does not give a positive indication for line clear.

In foggy weather the signals are often protected by detonators, except when they are repeated in the locomotive cab.

The *Nord Company* has inaugurated in front of the Paris-Nord Station a new arrangement for attracting the driver's attention in foggy weather.

The installation consists of luminous globes which repeat the aspect of the stop signals. They are placed on the ground in the four-foot way at every 50 m. (164 feet) and indicate by a block figure their distance in hectometres from the signal the train is approaching. These globes, which are called «pavés» (paving stones) show red or white according to the position of the signal which they repeat.

§ 7. — *We will examine here a few essential characteristics of the mechanical operation of signals :*

Railway.	Transmission by single or double wire.	Operating limit.	Control in the cabin.
France.			
State Railways.	Single wire.	2 500 to 2 800 m. (8 202 to 9 186 feet).	All distant signals are repeated electrically in the cabin, either visually or by bell. The other signals are repeated if they are not visible from the operating centre.
Alsace-Lorraine	Double wire.	1 200 m. (3 936 feet).	The signals not visible from the operating centre are controlled electrically by an optical repeater in the cabin.
Midi.	Single wire.	No limit is fixed. The operation is usually at 1 500 m. (4 920 feet). Exceptionally at 2 000 to 2 200 m.,(6 560 to 7 216 feet).	The home discs, the caution discs, and the distant green and white chessboards are fitted obligatorily with bell control. Likewise the absolute stop square signals, which are not visible from the cabin.
Paris-Lyons Mediterranean.	Single wire.	2 500 m. (8 202 feet).	Electric control of all covering signals which are not visible at all times from the cabin. All signals more than 100 m. (328 feet) away are considered as such.
Est.	Single wire.	No fixed rule, but when the distance exceeds 2 000 m. (6 560 feet), operation is by battery-fed motor.	The signals are controlled electrically in the danger position, and in certain cases where clear.
Paris-Orleans.	Double wire.	Practically no operation beyond 2 000 to 2 500 m. (6 560 to 8 202 feet).	All distant signals are controlled electrically.
Nord.	Single wire.	There is no operating limit beyond the muscular force of the signaller.	All signals which are not visible from the cabin, are controlled electrically, either optically or by sound.
Belgium.			
Belgian National Railway Company.	Double wire.	1 500 m. (4 920 feet) is rarely exceeded. Signals more than 1 500 m. from the cabin will in future be operated electrically.	The most distant signals are controlled electrically, as also those which, not being visible from the cabin, might by reason of local circumstances give doubtful indications.

CONCLUSION. — It seems that opinion is unanimous as to the need for electric control in the cabin of all distant signals, and of all signals which are not visible from the cabin.

Electrical operation is gradually replacing mechanical operation when the distance exceeds 1 500 to 2 000 m. (4 920 to 6 560 feet).

§ 8. — As regards the travel which the operating lever of a distant signal gives to the continuous transmission, it does not appear that any set rule is followed. There is, however, a general tendency to increase the stroke of the lever as the working distance increases.

On the *Est* this stroke may be as much as 0.750 m. (29 1/2 inches) and it is made directly by the lever which takes an angular path of 180 degrees.

§ 9. — Signals on the open road, which by reason of their distance from the cabin cannot be worked by continuous transmission, are power-operated.

Operation by compressed air, hydraulically, or by carbonic acid gas, does not seem likely to extend. On the other hand operation by battery-fed electric motor is extending.

The *French Est* states on this subject as follows :

As regards signals on the open road and those connected with mechanical interlockings, several thousands of these signals are operated by battery-fed electric motors.

These motors, of the « Est » type work by lifting a counterweight : when the signal is clear, the current is cut off from the motor, and a braking arrangement comes into action to keep the signal in this position.

The energy consumed is 100 joules (73.7 foot-pounds) per operation : the power required to maintain « line clear » is 0.032 watt. The current is supplied by a battery of 12 Leclanché cells, mounted in series of 6.

The contacts of the motor operating relays are formed by oscillating tubes containing a drop of mercury in hydrogen gas, thus reducing sparking and avoiding deterioration of the contacts.

§ 10. — *What is the method of working the points at intermediate stations on high speed lines, and which are situated at a great distance from the operating cabin ?*

Some attempts have been made to accomplish the working by continuous transmission.

The *French Nord* advises that points situated at 600 to 700 m. (1 968 to 2 296 feet) from their levers are operated by wire : the apparatus employed in such case is a winch operating a double wire transmission. Although this method has given satisfaction, it has not been extended, owing to the long time required for operation.

The battery-fed motor is now preferred.

§ 11. — Nothing particularly new is to be noted regarding the safeguards imposed in the case of the facing points of a turnout on the open road being run through at speed.

CHAPTER II.

Block system.

§ 12. — *What are the methods of block system in use ?*

Leaving out the automatic block we find no new tendency shown in the choice of a block system. Some railways continue to use the permissive block, others the absolute block. Each railway considers the arrangement it has in use sufficient for working requirements, and reliable.

The experimental results are insufficient to form a comparison between these two methods of working.

There is nothing new in the types of block instrument in use — « Lartigue, P. L. M., Regnault, Siemens.

Manual block working has the great disadvantage of high working cost, each cabin requiring in the daytime three men.

In order to reduce these costs on the *Belgian National Railway Company*, a certain number of block stations are worked from a distance by the man in the next station.

As it is applied exclusively to short sections (about 1 000 m. (3 280 feet) this arrangement does not cause any trouble; it is frequently employed :

1. At intermediate stations of lines with heavy traffic, where it is always advantageous to turn that portion of the road between the home and starting signals into a block section.

2. At the exit of termini where the existence of a short section increases the capacity of these stations.

The working of block signals from a distance is done either mechanically by continuous transmission, or electrically where there is a source of energy available.

Track circuits are provided to prevent a signalman admitting a train into an occupied section.

§ 15. — *Automatic block working. — In what cases is this method used ? What system would you prefer ?*

The *French Nord* has had automatic block working under trial since 1923 on a section of about 16 km. (10 miles) of steam operated road. The line is divided into sections of from 800 to 1 250 m. (2 624 to 4 100 feet). The track circuits and motors are battery-fed.

The signals are of the usual type: large semaphore arms, repeated by boards standing normally at « clear ».

The signals are lit by acetylene gas day and night : fixed light on the semaphores, flashing on the repeaters.

The working methods are the same as for manual block : interdependence of the sections, interdependence of the repeater and its semaphore, permission to pass a signal at danger after handing the driver a permit, and cautious running in the section.

The stations are enclosed by semaphores, which assure protection while shunting, which allows the red discs on this section of the line to be eliminated.

Within the block section current from batteries is used.

The relays are of the direct current type, and two-position.

The road is laid on wooden sleepers. The circuits are insulated by fibre joints. The ends of the rails are connected together.

There are no impedance bonds.

The signals are operated by low voltage D. C. motors.

The signals are of the usual type.

The working of the automatic block gives as regular a service as the manual block.

The different pieces of apparatus (relays, track circuits, signal motors) work satisfactorily.

As this installation, put down for trial in 1923, comprises some mechanical apparatus, it was thought advisable to guard against a possible failure of those parts, by interconnecting the sections so that the clearing of one signal will hold the arm of the preceding signal at danger.

This arrangement is similar to that which is provided by manual block working, and is a safeguard against a signalman forgetting to restore the arm to danger.

However, with automatic block working, some installations are so arranged that the signal held at danger does not remain there permanently, but returns to line clear as soon as the train has passed the signal next after the defective one, provided that the two sections in question are clear of all traffic.

It may here be remarked that experience is demonstrating the possibility of abandoning the interdependence of sections, the safeguard of which has more disadvantages than advantages in practice, due to the complication of circuits which arises and their hindrance to traffic by imposing, under certain conditions, cautious running through two successive sections, when a block signal has been encountered at danger.

As explained above, the interdependence of the sections was only established on the line under consideration on account of the working of the mechanical apparatus, and not because of the working of the relays.

The automatic semaphores are equipped with a detonator : a cartridge explodes every time the signal is passed at danger.

Before entering a blocked section, the driver must stop in front of the signal.

The guard cancels the detonator only once, and hands the driver a permit to pass the signal at danger and proceed cautiously.

The detonator, which introduces a new complication into signalling, is a delicate mechanism and costly to instal.

The *Nord Company* is considering, in future installations, repeating in the engine cab the stop position of a block signal passed at danger.

In the existing plant, a chronograph installed by way of experiment on each semaphore of this trial section, acts as a control apparatus every time a driver unduly passes that signal at danger.

The stations are protected by automatic semaphores which can be set at danger from the station by moving the lever located in a central electro-mechanical locking frame.

In the position « signals at line clear », the levers lock the keys on the Bouré locks which allow the normal position of the point levers in the station to be changed.

This arrangement, like that already described, does away with the red disc.

As regards the operating costs of automatic block and manual block respectively, experience shows that the working costs (material and labour) of an automatic block station comprising-

2 main signals,
2 repeaters,
2 fixed contacts,

with their accessoires, are not more than 1 500 fr. above the same costs for a manual station : on the other hand the automatic block shows an important saving in staff.

The *Est Company* has employed up to now the automatic block for train protecting signals. This block is permissive like the Lartigue block, but whilst for the latter the passing of a signal must always be authorised by the signalman, in the automatic block it is allowed by the guard.

The automatic block only comprises short sections of 2 km. (1.24 miles) and it does away with the protection of trains held up in the open road.

To signify that it is both a spacing signal and a protecting signal, the semaphore of the automatic block has been given a slightly different shape to the Lartigue semaphore. This has a racquet shaped arm, whilst the semaphore of the protecting signal is rectangular (or more exactly slightly trapezoidal).

The signals in each section consist of a semaphore repeated by a chessboard.

These signals are normally « clear ». They go to danger directly the engine has passed the signal, and they do not return to line clear until the road is free up to the next signal at danger, and duly announced.

The track circuit is most generally fed with D. C. from batteries of the AD type, of which the installation is easy, the electrolyte non-corrosive, maintenance very low, and sensitiveness to variations of temperature negligible.

Each of the two sets of rails is insulated. The lengths of sections are very variable. It is sufficient if, under unfavourable conditions, the insulation resistance exceeds 1 ohm.

In practice, an average of 1 500 m. (4 920 feet) may be depended upon. When the roadbed is good, 2 000 (6 560 feet) has been exceeded.

The track relays are multiple-contact, in sealed cases, and are adjusted once for all in the factory. Mechanism and contacts are visible through a glass panel. The resistance to the coils is 1 ohm or 4 ohms according to requirements. The working is assured at 0.03 watt minimum.

The armature returns to the neutral position when the power falls below 0.01 watt.

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This automatic blocks is satisfactory.

The reliability of the apparatus in service is equivalent to that of the apparatus used in manual block working controlled by track circuit.

Cases of false line clear indications by the relays are rarer than mistakes by men working the signals.

The working of the automatic blocks is very regular. The number of faults reported with this block system is less than that shown with manual block working.

The passing of signals at danger into a blocked section is regulated as follows :

1. If it is a train protection signal the guard after waiting 3 minutes, gives the driver a written note stating that the section is blocked, then authorises the driver to pass the signal at danger. The driver must keep his train under control and be prepared to stop in the portion of the line in view if he sees an obstruction or a signal at danger. He cannot resume normal speed until having passed at line clear the signals of the two sections following that of the blocked section.

2. If it is a definite stop signal, the guard after waiting 2 minutes, communicates with the signalman of the cabin or station controlling the signal. If a failure of a signal is detected, the passing is only authorised after the guard has verified that the line is clear up to the section signal of the next post, and the delivery by the signalman to the guard of a note (of which he must inform the driver) instructing him to protect his train if it should be held up before having completely passed the next section signal, and to proceed cautiously until two section signals following that governing the blocked section are passed.

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The total annual cost, including sinking fund, wages, and running expenses (lighting of signals, track circuits, batteries, relays, motors, etc.) per kilometre of single track, is estimated at 11 000 fr. (17 600 fr. per mile) for manual block in sections of 2 km. (6 560 feet), and at 7 000 fr. (11 200 fr. per mile) for automatic block in sections of about 1 500 m. (4 920 feet).

The *Paris-Orleans Company* has only made three trials of automatic block on three small sections :

a) 3 km. (1.86 miles) of electrified double track between the two Paris stations (Quay d'Orsay and Gare d'Orléans), employing alternating current.

b) 9 km. (5.6 miles) of double track, with a single automatic block station between two Lartigue block stations (battery fed).

c) 6 km. (3.7 miles) of single track (battery fed).

The chief characteristics of these installations are :

A. — *Alternating current block.*

Polarised block, with three-aspect light signals.

6 sections averaging 500 m. (1 640 feet). Each signal is repeated only by the preceding one, the speed of the trains being low (50 km. [31 miles] per hour).

Track relays : 2-element, 3-position, 50 cycles.

Impedance bonds, 1 000 amperes per rail (impedance 0.35, 1 volt and 50 cycles).

B. and C. — *Battery-fed block.*

Semaphore arms, repeated at 1 000 m. (3 280 feet) by green and white chessboards. All signals operated by battery-fed motors.

Sections of 3 to 5 km. (1.86 to 3.1 miles).

Track circuits of 800 to 1 200 m. (2 624 to 3 936 feet).

Neutral track relays of 4 ohms. (In the 1 200- m. (3 936 feet) circuits with bad insulation, it has been necessary to replace the 4-ohm relays by 2-ohm relays.

2-volt batteries for the 4-ohm relays and 1 volt for the 2-ohm relays. Copper sulphate cells.

These automatic block trials are on too short sections for a serious comparison with the manual block. The track relays have never given false indications.

The *Midi Railway* utilises automatic block very largely on its main lines, double track. 655 km. (407 miles) fitted.

The features of the automatic block installed on electrified lines as well as on steam-worked lines are the same, and are as follows.

The automatic block comprises essentially :

A division of the line into block sections (the average length of the section is 3.5 km. (2.17 miles).

Signals, usually 2 per section, automatically protect the sections. A section semaphore protects the section locally; an advance disc repeats the semaphore.

The block signals go to danger automatically and successively directly the first axle of the train passes over a special joint (block joint) placed 30 m. (90 feet) beyond the signal.

The disc and the semaphore protecting a section « clear » behind a train (though still indicating) « danger », as soon as the train has passed the semaphore protecting the following section (more exactly the block joint of this semaphore).

The disc and the semaphore of a released section, though still closed, clear automatically and simultaneously as soon as the train passes a special spot (annunciator joint) placed at a certain distance in front of the disc.

This block system is therefore « road normally blocked ».

The signals referring to the up and down roads are generally placed near to one another. Together, the up disc and semaphore, and the down disc and semaphore, form the signals of the same block station.

All main stations are block stations. The section signals are placed on each track at the exit of the station.

Intermediate block positions are created when the distance separating two consecutive stations exceeds a certain length.

Station block section discs are also used for protecting the station.

In the stations a special semaphore (home signal) automatically protects a train standing in the station. This is fitted with a blocking joint like the other block signals. It releases at the same time as the disc and block semaphore between which it is located. It clears by the action of the repeating joint of these signals.

It clears also by the action of a joint placed 50 m. (164 feet) in front of it, if the block section beginning at the semaphore of the station block section is occupied, provided that the road is free up to that semaphore. But although the home disc at clear, or the section semaphore at clear, releases the driver from the obligation to proceed cautiously imposed by a preceding block signal, finding a home signal at the station at clear does not in any way change the running conditions of the train. The home signal is not really a block signal, but a local automatic protecting signal.

The home block disc has occasionally nearly the same significance as an ordinary home disc.

The block semaphore requires a stop in front of the signal. It may be passed, even at danger, after a wait of five minutes on handing the driver a permit to proceed cautiously. The block is therefore permissive.

The home signal at danger, of a station in service, requires a stop. It may only be passed by a calling-on signal from the station.

Any accidental stop of a train outside a station in service, requires immediate protection in the rear by the guard at the end of the train, except when the stop is due to a block signal at danger. In this case, the protection is not obligatory until after a wait of five minutes.

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Automatic block signalling on the *Midi* electrified lines have A. C. track circuits (1).

Track relays are two-element. The well-known advantage of a relay of this type over the single-element type is that it requires for its operation much less current from the track circuit.

The relay used by the *Midi Company* consists of a squirrel cage motor mounted on ball bearings, and a stator consisting of a « local » winding round four main poles and fed at 110 volts, and a track winding round four auxiliary poles and connected directly to the high tension winding of the impedance bond.

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(1) See *Revue générale des Chemins de fer*, July 1927. Le bloc automatique sur les lignes électrifiées de la Compagnie des Chemins de fer du Midi (Automatic block working on the electrified lines of the Midi Railway Company), by M. G. Gilles. We extract from this very interesting review the following explanations.

The relay is excited only under the two following conditions :

1. If the voltage on the terminals of the track winding is sufficient.

2. If the current in the track winding is sufficiently displaced in relation to the current passing through the local winding of the relay.

To obtain the first condition, the pressure of the current must be proportionate to the length of the track circuit. It must be remembered that the track circuit is a very bad conductor of electricity. The insulation resistance between the rails of a tract circuit 1 km. (0.62 mile) in length varies from 1 ohm in wet weather to 10 ohms in dry. The signalling voltage between the rails falls very rapidly in consequence of the losses.

To obtain normal working, the variation of potential at the terminals of the track winding of the relay should be between 1.8 and 2.5 volts.

To obtain the second condition, it is necessary to give a value corresponding to the relation between the inductance and the ohmic resistance of the source which feeds the impedance bond. With this object a resistance is inserted in this circuit, which is adjusted, and which acts also as a protection for the feed transformer, without which it might be overheated by the too high current absorbed when the secondary is short circuited by the axle of a train on the track.

For track circuits exceeding 1 400 m. (4 592 feet) in length, it is necessary to insert a condenser of four microfarads in series with the local winding of the relay in order to obtain the phase displacement and the maximum torque.

The preceding figures assume a very careful bonding of the joints, which is otherwise absolutely indispensable, not only to assure the return of the traction current, but also to operate the track circuit by impedance bonds, whenever the length of the circuit exceeds 500 m. (1 640 feet).

It is obvious that on steam lines in the immediate neighbourhood of electrified lines, the feeding of the track circuits by battery must de replaced by alternating current, otherwise the leakage of the D.C. traction current into the ballast might be taken up by the rails of the insulated sections of the neighbouring steam road, and cause unintentional excitation of the D.C. track relays.

It is no longer necessary to instal impedance bonds : it is sufficient to connect to the rails in front of the insulated section the track winding of the A.C. relay, and behind the insulated section the secondary winding of a small 110-volt 5 to 10-volt transformer, in series with an iron core impedance, the object of this adjuster being to obtain the phase displacement required between the currents passing around the two windings of the relay, to allow this to operate on the one hand, and on the other hand to cut off the current when an insulated section is occupied by a train.

Automatic block with A.C. track circuits has been in operation on 17 km. (10.6 miles) between Coarraze Nay and Pau (line from Toulouse to Bayonne) since January 1924; on 12 km. (7.5 miles) between Toulouse and Portet St.-Simon (line from Toulouse to Bayonne) since April 1925; and on 147 km. (91.3 miles) between Bordeaux and Dax (line from Bordeaux to Irun) since March 1927.

⁂

The *Midi Company* is of opinion that automatic block is much safer than manual block, and in particular the Regnault block system, which is not proof against trickery. The automatic block has the further advantage of eliminating the human failures on the part of the manual signalmen.

Of course, no system invented by man will ever be perfect. On the *Midi Railway* every unintentional clearing of a signal noted gives rise to an immediate enquiry on both sides. One can thus estimate with certainty the degree of perfection arrived at by the automatic block in use The probability of the unintentional clearing of a block signal with the *Midi* type of automatic block is as 1 to 10 million times signals are passed by the trains.

* * *

Very complete statistics of irregularities are kept constantly, from which it is found that the average number of irregularities per day is 1 per 100 km. (62 miles) of double track fitted with automatic block.

The average number of irregularities of signals found wrongly at danger by trains is approximately 7. As each irregularity blocks 1, 2 or 3 signals (sometimes even 4) this figure is about equal to an average of 4 trains delayed or stopped per irregularity.

Working costs. — To arrive at a comparison of the automatic block systems on the *Midi* steam and electric roads, either between these two, or with the manual block, we will take the corresponding costs for the year 1924, which give the following table :

Approximate cost of installation per km. (per mile).	Midi automatic block for double track. Steam road.	Midi automatic block for double track. Electric road.	Lartigue manual block with the same block sections.
	Fr.	Fr.	Fr.
Approximate cost of installation per km. (per mile).	25 000 (40 000)	45 000 (72 000) (1)	6 000 (9 600)
Interest at 8 °/o p/a.	2 000 (3 200)	3 600 (5 760)	480 (768)
Approximate annual cost per km. (per mile) for operation, maintenance and repairs.			
Material	800 (1 280)	1000 (1600)	200 (320)
Repair men	1 100 (1 770)	1100 (1760)	100 (160)
Operators	—	—	7 800 (12 480)
Total. . . .	1 900 (3 050)	2100 (3360)	8 100 (12 960)

(1) In this figure no account is taken of the electric bonding of the road, necessary amongst other things to ensure the return of the traction current under good conditions, nor of the installation of the 10 000-volt three-phase line, which on the Midi Railway, distributes the current to the stations and along the line, and is not kept for the exclusive feeding of the automatic block.

The annual amounts to be compared in order to determine the economic value of the various systems are therefore :

2 000 + 1 900 = 3 900 fr. for the automatic block on steam road.

2 600 + 2 100 = 5 700 fr. for the automatic block on electrified road.

480 + 8 100 = 8 580 fr. for manual block.

It will be seen, therefore, that for electric lines the installation of automatic block costs nearly double that of the ordinary automatic block for steam lines, but in spite of this, in view of the high wages actually paid, the economic advantage of the automatic block over the manual block still remains very high on the electrified lines.

It should be remarked, however, that this conclusion is only valid, strictly speaking, for intensive traffic lines.

As a matter of fact on roads where the traffic is not so heavy, that there might be a serious objection :

to extending the average length of the block sections to the distance between successive stations;

to having the signals at stations served by the station staff;

to having the signals on the road, where such exist, served occasionally by the gate-keepers at level crossings;

to cutting out at night the semaphore signals at stations, and even the stations themselves at least in the proportion of 1 out of 2, the Traffic Department then spacing in consequence the trains during the night, taking into account the increased length of the sections;

there is no doubt that manual block working might regain the advantage from an economic point of view, because automatic block working should certainly be intended from the start for controlling trains run as closely together as possible in peak periods, however exceptional may be this running.

⁂

The *French State Railways* use automatic block with light signals. This system has been applied to a large part of the suburban lines, which are both electrified and steam operated.

45 km. (28 miles) of double track have been equipped with automatic block daylight signals with luminous panel signals having aspects in conformity with the rules in force for signals at night.

Trials are also being made of automatic block working with mechanical signals, consisting of track circuits and D.C. signal motors. These trials have been satisfactory.

The systems employed space out the trains by the automatic setting of the signals at the entry of each section and by keeping them at danger during the whole time the section is occupied.

The track circuits extend over the whole length of the sections to an average length of 700 m. (2 296 feet). The installations are usually fed by alternating current, 25 cycles, distributed at 1 500 volts and reduced to 110 volts in the transformers at the base of the luminous panels.

The track relays are :

Vane or rotary field,
1 or 2-element,
2 or 3-position.

The different track circuits are divided by insulating joints consisting of four semi-fishplates with insulation of cellulose impregnated with synthetic rosin.

On the electric lines the return of the D.C. traction current is assured by impedance bonds. These are of various types :

1. *simple* (fig. 1).

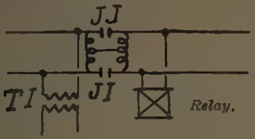


Fig. 1.

2. *resonated* (fig. 2)

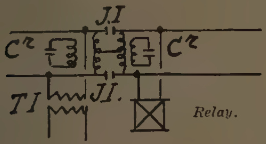


Fig. 2.

3. *with high tension windings connected to the bond itself for collection and applying the track current* (fig. 3).

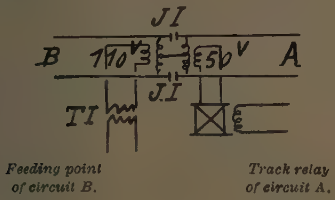


Fig. 3.

The first type has a tendency to increase the consumption of the alternating current.

The second type avoids this excessive consumption, but has the disadvantage of being sensitive to variations of frequency.

The third type is above all sensitive to variations in the intensity of the traction current.

The panel signals are 1.50 to 1.75 m² (16.1 to 23.6 square feet). They are mounted either on posts or gantries.

* * *

The electrification of the suburban lines has given rise to a great increase in traffic : hence the necessity of obtaining by automatic block working a more rapid circulation than is possible with manual block.

During the four years that the block system with day light signals has been in service on the French State Railways, no false indication due to the relays has caused a dangerous condition. It has been found that occasionally relays are de-energised wrongly, putting signals to danger, but in no case has a clear signal (white light) been wrongly given.

The working of the installations is very regular. No special measure contemplates the passing of a signal at danger, this being rigorously forbidden by the rules in force.

A semaphore light may be passed after stopping and handing the driver a permit to proceed to within sight of the next panel signal.

The red lights of square signals are impassable in the same conditions as the mechanical red square signals.

It has not yet been possible to figure exactly the cost of operating the new system, but as regards the installations of mechanical signalling which have had to be put in to provide for the intense traffic of the suburdan electrified lines, it can be said that the daylight system is not more costly than the old signalling.

* * *

The *Paris, Lyons and Mediterranean System*, the *Alsace-Lorraine Railways* and the *Belgian National Railway Company*, do not use the automatic block.

CONCLUSIONS.

The *French Railways* which use automatic block are satisfied with it as regards both safety and regularity.

We find, however, that generally during the past five years the substitution of automatic block working for manual has been very slow, notwithstanding the growing importance of operating costs.

The *Paris-Orleans* has installed on 9 km. (5.6 miles) of double track an automatic section between two signaled sections. It has also installed automatic working on 6 km. (3.7 miles) of single track.

The *French State Railways* have extended automatic block on about 25 km. (15.5 miles) of double track of suburban lines.

On the other hand the Paris-Lyons-Mediterranean which since 1898 has had on trial an automatic installation on 38 km. (23.6 miles) of double track, does not possess at this moment any section of line equipped with automatic block.

The progress of automatic block working is actually very modest.

Automatic block working has, in effect, an economic advantage over manuel block, only in cases where the intensity of traffic is such that the length of the sections must be reduced by creating signal positions on the open road which cannot be controlled from level crossings, and require in consequence an increase in staff.

Automatic block working, therefore, is not to be contemplated on even busy lines where the distance between successive stations is short.

⁂

We have also been able to note that very different systems of automatic block working are satisfactory as to safety and reliability.

On the *Nord Company :*

Indication normally clear.
D. C. track circuit, battery-fed.
2-position relay.

The relays and track circuits work satisfactorily.

The reliability of working is comparable to that of manual block.

Est Railway.

Indication normally clear.
Track circuit D. C., battery-fed.

Cases of false indication of line clear by the relays are rarer than mistakes by men operating the signals.

From the point of view of reliability the number of interruptions recorded is less than that reported with manual block working.

Paris-Orleans Company.

Indication normally clear.
D. C. track circuits battery-fed, and
A. C. track circuits.

The trials are on too short sections for a comparison with manual working. But the track relays have never given false indications.

Midi Railway Company.

Indication normally at danger.
Both A. C. and D. C. track circuits.

The company considers that automatic block is more reliable than manual. and in particular than the Regnault block. It has further the advantage of eliminating the human failings on the part of the men operating the manual system.

The likelihood of a block signal « clearing » wrongly is 1 in 10 millions.

As to interruptions, caused by unintended stopping of trains, they are at the rate of 1 per day and per 100 km. (62 miles) of road.

French State Railways :

Indication normally clear on steam operated and electric lines.

During four years no false indication caused by the relays has endangered the traffic.

The working of the installations is very regular.

⁂

It has not always been possible for us to compare the different types of automatic block in use : we do not possess particulars of all the failures, nor the report as to their cause.

It would seem that the system of line normally clear is preferred to that of line normally closed. This latter is actually more complicated and costs more to instal. On the other hand, since the employment of light signals, the risk of signal arms freezing up at « clear » has disappeared.

The system of « line normally closed » is therefore only superior to that of « line normally clear » from the point of view of safety when mechanical signals are used operated by electric motors.

⁂

Another conclusion which may be related is that of the superiority of A. C. track circuit over D. C. track circuit, the working of which may be affected by stray currents.

CHAPTER III.

Daylight signals.

Where employed. — Types in use. Advantages.

§ 16. — The *French Nord*, the *Paris-Lyons & Mediterranean*, the *Alsace-Lorraine Railway Company*, do not use day light signals, but are studying the principle of their application.

The *Est Company* has as yet only installed a small number of light signals by way of trial. Their operation having been satisfactory in every way, the Company intends to undertake much more comprehensive trials.

The *Midi Company* has as yet only installed light signals on a recently opened line.

The trials made by this Company prior to this installation have demonstrated the superiority of these signals from the point of view of visibility. The working, regardless of distance, is also more reliable than that of mechanically transmitted signals. Finally is to be borne in mind the relief from the burden of having to light up the signals daily. This advantage gives a saving in staff, which in certain small stations might even allow a signalman to be dispensed with.

The power employed for these signals is A. C. at 110 volts. It is stepped down to 8 volts for the lamps.

The light is steady — not flashing.

Each unit (red, white or green) comprises a cast iron case containing two lenses, one of which one is stepped, an arrangement designed to present smooth exterior surfaces and facilitate cleaning. A double filament incandescent lamp of 15 watts, 8 volts, has its two filaments placed in the optical focus. As the line has many gradients and curves, it has been necessary to provide a certain deflection (12°) so that the signals shall be visible at short range. This has been obtained by the use of a specially long filament in the lamp.

The *Paris-Orleans* has introduced light signals on the electrified lines on account of their visibility (disc signals being difficult to pick up amongst the overhead catenary).

The good results obtained, from the point of view of both visibility and reliability, have led this Company to extend the use of the new signals. More than 500 daylight signals are installed in 5 main stations, and on a four-road section near Paris.

The costs of installation vary, but are about the same as motor-operated disc signals.

The lights are steady, not flashing : they are fed by alternating current.

The following are the particulars of the different types of light in use :

a) Doublet lens (two stepped lenses, of 150-mm. [6-inch] diameter). The inside lens coloured (the outer white), with double-filament lamp, 6-8 volts, 12-16 watts.

b) The same, but with 210-mm. (8 1/4-inch) lenses, 8-watt lamps.

c) Three doublet lights of 80-mm. (3 1/8-inches) grouped in a triangle ($^0{}_0{}^0$) with 3 lamps, 6 volts, 6 watts.

d) A unit of 1 single lens, white, of 150 or 200 mm. (6 or 8 inches) and a reflector. The colours are given by fixed or mobile roundels. The mobile roundels are operated by a relay, and allow two or three indications with the one light. The reflection is obtained by silvering the light bulb (6 volts, 10-18 watts).

The *French State Railways* uses light signals on all the suburban lines, and in places on the main lines.

The drivers and guards of the electric trains appreciate the good visibility of the aspects of these light signals by day, whatever may be the sighting distance.

The working is unaffected by atmospheric disturbances.

The average cost of installation, including background, lenses, lamps and mounting are :

6 000 fr. for a signal of 8 lights.
5 100 fr. for a signals of 6 lights.
3 400 fr. for a signal of 3 lights.
3 300 fr. for a signal of 2 lights.

The annual cost of maintenance, including replacement of lamps and the lighting current, is about 170 fr. per light in service.

The power employed is electric (A. C.).

Lights are steady.

Usually :

Each light unit comprises 2 lenses, one in front of the other, of a useful diameter of 150 mm. (6 inches) and a two-filament lamp of 16 watts, 8 volts, the coloured lens being placed inside.

Another arrangement comprises for each light, three aspects, of which the centres are equi-distant. There is one lamp of 6 watts for each aspect.

Each aspect is formed by two double-concave lenses of moulded glass, abutting one on the other, and having circular concentric ribs.

CONCLUSION.

The use of light signals is extending progressively on the suburban lines with heavy traffic, where the block sections are very short and where the signals are consequently very numerous.

On main lines light signals are employed where there is automatic block working, and also when they are electrified.

Outside of these, the use of light signals appears very limited, no doubt on account of the heavy cost of installing the necessary electric cable.

The different types of lights tried appear to be giving every satisfaction. No advantage has been claimed for any particular system. The duration of the trials is really too short to justify an opinion in this respect.

CHAPTER IV.

Signalling in main stations.

1. — The position has scarcely changed since 1925. Therefore, we will refer to the reports of the London Congress.

Electric power operation is coming more and more into favour for main stations. It is actually safer than mechanical operation, and enables a considerable increase in the capacity of the station. Also, it is very little subject to wear, and does not call for heavy upkeep. Usually a central cabin is installed at each end of the station. However, in several stations control from one central cabin has actually been installed.

The *Nord Company* has an experimental installation at Laon, when one central electric cabin (Mors) controls a zone of 1 400 m. (4 592 feet). The most distant points are 750 m. (2 460 feet) from the cabin, and the most distant signal 840 m. (2 755 feet). The results are very satisfactory.

The *Midi Company* has put in a central cabin in two stations.

In the opinion of this Company it is only possible to establish such posts in relatively compact stations, where the various installations are conveniently grouped, so that the view of the signalman may extend over the whole station placed under his entire control. Whenever the condition of good visibility is fulfilled, it is certainly advantageous to concentrate into one single operating position the control of the various safety appliances. The signalling staff being made better use of, can usually be reduced.

On the other hand, even if the central cabin must be served by several men, together, the relations which must necessarily be established between them are incomparably easier when they are placed side by side in the same cabin, than if they are looking after the working of two cabins, more or less distant from each other.

1. The *Belgian National Railway Company* has two central cabins which control all locations within a zone of more than 2 km. (1.24 miles) in extent. This is a very convenient method whenever there are no shunting movements to be made beyond the range of vision of the signalman

The single cabin is an advantage from the point of view of the better utilisation of the signalling staff. It abolishes communications between cabins, simplifies the communications between the traffic manager and the signalmen; and for this reason even reduces the risk of errors from misunderstanding the communications.

On the other hand, centralisation in one cabin involves running a lot of cable, which makes it costly to instal.

2. We notice that on most of the railways, the entry to passenger roads in main stations is covered by track circuits.

In most cases direct current is used, and forms a reserve of power. In this respect the *Paris-Orleans Company*, expresses the following opinion :

« We use A. C. on our electrified roads. The absence of a reserve of power is an evident drawback, and obliges us to have alongside the normal supply, one or two standby sources.

» In the large installations using A. C., we usually have light signals, which must not be extinguished for more than a few seconds.

» We have therefore standby generators with automatic starters, which are fed by a battery of accumulators. »

Review for the discussion.

I. — Methods of signalling and type of the signals.

No modification has taken place since 1925 in the methods of signalling, nor in the type of the signals used by the *French* and *Belgian Administrations*.

The numerous functions of these signals are :

1. To protect dangerous positions nearby.
2. To protect dangerous positions at a distance.
3. Route indication.
4. Speed indication.
5. To indicate the lie of the points.
6. To protect block sections.

One signal sometimes performs more than one duty.

No tendency has been observed towards greater uniformity in the signalling of the different lines.

On heavy traffic lines it would seem desirable to abandon disc signals which turn sideways for line clear, and to replace them by semaphore arms, which always give a positive indication.

For purposes of simplicity it seems desirable also to use for a signal covering an absolute block section the same form as for a signal protecting a position of danger.

It would further appear higly desirable to standardise on the different railways the colours of light signals which perform the same functions.

II. — Control of the signals.

Electrical control in the cabin, of the position of the distant signal, is general.

Running signals at great distances from the cabin (1 500 m. = 4 920 feet and above) are being more and more operated by power. Operation by compressed air, water under pressure, or carbonic acid gas is not likely to become general. On the other hand, operation by battery-fed electric motor is extending. The same type of motor is also being used for working outlying points at intermediate stations.

III. — Automatic block.

In a general way, railways which are using automatic block are satisfied with it as regards both safety and reliability.

Yet, during the last five years, automatic block has only displaced manual block very gradually, notwithstanding the growing importance of labour costs.

The reason is to be sought in the fact that automatic block only offers advantages from the financial point of view in cases where the traffic is so dense as to necessitate shortening the block sections by establishing signalling stations which cannot be operated from level crossings, and therefore require an increase of staff.

As regards the different types of automatic block in use, «line clear» normally seems to be preferred to « line closed ». The latter is actually more complicated and more expensive to instal. On the other hand, since the employment of daylight signals the risk of signal arms normally at « clear » freezing up disappears.

IV. — Daylight signals.

It is chiefly on busy suburban lines, where the block sections are very short, and where consequently the number of signals is very great, that daylight signals are in favour.

On main lines they are used where there is automatic block and also where electric traction is employed. Otherwise their use is very limited, doubtless because their first cost is very high and their visibility by day is not superior to that of the ordinary signal.

The various types of daylight signal tried seem to be satisfactory, but the duration of the trials is doubtless insufficient for a definite opinion to be formed.

V. — Signalling of main stations.

Electrical operation of points and signals in a main station from a central cabin is extending rapidly. It is to be recommended because it gives the maximum of safety, increases the capacity of the station, and enables the cost of maintenance to be reduced.

Of late years, control from one central cabin has been tried on several railways. The central cabin eliminates delays and errors arising out of communications between men in different cabins. It also allows a better use of the signalling staff. It is to be recommended wherever there is no shunting to be done outside the field of vision of the signalman.

In view of the necessity of having a reserve of electric power, alternating current is only very rarely substituted for direct current in electrical control from a central cabin.

List of questions which have been submitted to the French and Belgian Railways.

A. — Signalling of the lines.

1. — Are the methods of line signalling uniform throughout the railway, or do they vary with the importance and speed of the traffic ?

In other words, do you use one type of signalling for fast traffic lines and another for slow ?

Give a concise explanation of your signalling methods.

2. — How are the signals located in relation to the position of danger ?

Is the distance between the distant signal ant the nearby signal uniform, or does it vary with the speed of the trains, the profile of the line, the system of braking, and the load of trains ?

3. — How do you give route indication to the driver ?

Is this given by the nearby signal and by the distant signal covering the dangerous point, or by one only of these two signals ?

4. — Are speed indications given to the driver by the signals ? If so, how ?

5. — Are the block signals of the same kind as those which protect dangerous points ?

6. — Give a detailed description of the kind of signals used by day and by night.

Are these signals satisfactory ? At what distance are they visible ?

Are they sufficient in foggy weather ? If not, how is the signalling supplemented then ?

7. — What are the methods employed for mechanical operation of signals ?

Is the operation by single or double wire ?

Beyond what distance in mechanical signalling forbidden ?

Do you repeat the position of the signals in the cabin ? When and by what means is this done ?

8. — By what type of apparatus are the mechanical signals operated ?

(Type and stroke of the lever, of the compensating apparatus, etc.)

In the event of a wire breaking, does the signal go to danger automatically ? If so, by what means ?

9. — What system is employed for power signalling? (Electricity, compressed air, etc.).

Indicate the method of operation (apparatus in the cabin, kind of power, transmission, etc.).

10. — Are there, at intermediary stations on fast lines, points operated from a distance ?

How is this done ? By continuous transmission or by power ?

Give a detailed description of the apparatus used in the installation.

11. — What precautions do you impose in the event of a facing point at a junction on the main lines being run through at speed ?

B. — Block system.

12. — What block system is in use on your railway ? Is it uniform throughout the lines ?

13. — What types of block instrument are used ?

14. — Have you any block signals operated from a neighbouring block station ? If so, state the operating distance, the methods adopted for distant operating, particulars of the apparatus (levers, continuous transmission, power, signal motors, relays, etc.).

15. — Do you use automatic block ? How is it effected :

1. On steam roads;
2. On electric roads ?

16. — Give a detailed description of each of the automatic block systems in use.

State particularly :

Current employed;
Length of the block sections;
Type and characteristics of the relays;
Insulation of the track;
Impedance bonds;
Interlocking apparatus;
Type of signal.

17. — Make a comparison between automatic working and manual block, from the following different points of view :

1. Safety. (Is not a false indication by the relay to be feared ?)

2. Reliability. (What precautions are laid down for passing signals at danger ?)

3. Operating costs.

C. — Daylight signals.

18. — When do you use daylight signals ?

In what respect do you consider them advantageous ?

Safety : Visibility.

Ease of recognition by the driver.
Reliability, irrespective of distance and atmospheric conditions.

Cost of installation and maintenance :

19. — What power do you use for daylight signals ? (acetylene, electricity) ?

Are the lights steady or flashing
Give a detailed description of the optical apparatus.

D. — Signalling in main stations.

20. — By what methods are the main stations worked ?

Are some tracks, uni-directional, others double ?

Are some roads reserved for non-stop trains, others for stopping trains ?

What communications have to be exchanged between the men in the central signal cabins on the one part, and between them and the station master on the other part, before accepting a train into the station ?

Distinguish between :

1. Normal working;
2. Extraordinary working.

Is the block system discontinued within the station ? If not, over what station roads is there continuity of block working.

21. — What are the general principles which govern signalling in main stations?

Are the signals repeated in the same way as on the main road ?

Do they give a speed indication to incoming trains ?

22. — Do you use shunting signals ? Describe them.

23. — In what instances do you use mechanical operation and power operation of points and signals ?

24. — What are the safety rules for mechanical operation (Locking, control of the points and plungers, detector bars, through lockings, length and division of the routes, etc.) ?

Ditto for power operation ?

25. — Is the occupation of the road controlled by track circuit ? In what instances ?

26. — Give the method of working and the chief characteristics of the mechanical signalling apparatus.

Say also how a signal works, the clearing of which is dependent on two distinct signal stations.

27. — State the method of operation and the chief characteristics of electric signalling apparatus.

Do you employ apparatus operated by alternating current ?

What advantage does it offer over apparatus actuated by continuous current ?

Is the absence of a reserve of power (accumulators) a serious drawback ?

28. — Do you prescribe any limits to the centralisation of operation in main stations ?

[621 .138.5 & 625 .26]

Recent types of sand blast machines for railway workshops,

By W. RUDOLPH,
Regierungsbaumeister, Altona.

Figs. 1 to 17, pp. 752 to 770.

(*Glasers Annalen*, Nos. 1233 and 1235, —1928.)

On the railways, sand blast apparatus are principally employed for mechanically removing rust from plates, girders, sections and ironwork, for fettling castings in foundries, for cleaning locomotive boiler tubes, in particular, also the tube ends before they are expanded in the tubeplate, for cleaning locomotive boilers inside and outside, for the removal of old paint and rust from the frames and plate panels of rolling stock, from bridges and buildings constructed of metal, and, finally, for cleaning the facades of railway buildings.

The action of the sand blast apparatus consist of hard quartz sand, or, for some time past, under certain determined conditions, of steel particles or dust, being driven by a current of air, at a high speed, on to parts to be cleaned, and by these means a clean metallic surface is obtained.

One particular advantage of this process is that the metallic surfaces which, with a view to the application of a coat of paint or varnish, have been submitted to the action of the sand blast, lend themselves more readily to receive the protecting medium, allow it to adhere more strongly on account of the slight roughness of the surface, and make it last longer by reason of the absence of rust on the prepared surface.

The penetration of the sand jet in all the cavities and grooves, without damaging the sharp edges, sharp points or ornaments as well as the fact that in a fraction of the time which was formerly necessary the cleaning can be carried out with a perfection and uniformity that it is never possible to obtain by hand, offers advantages which compel engineers to abandon the old cleaning methods.

Chemical scouring has also been almost completely supplanted by the sand blast, and one of the main reasons for this is that the part treated by the sand blast is immediately ready to be put back into service, without rinsing or cleaning.

Castings which are used without any machining being done on them, and which must therefore have a clean surface are usefully dealt with by the sand blast. But the advantages of this process of cleaning are shown also with regard to fittings and parts which are completely or in part machined.

Every Works manager or foreman knows to what extent the cutting tools are damaged if care is not taken beforehand to remove the hard skin from castings, or, for plates, rolled sections, forged parts and press flanged plates, — the layer of scale. Cleaning beforehand by sand blast therefore results in a notable economy in tools and an appreciable decrease in production costs.

It is necessary to explain, as regards sand blast machines, the difference between the suction system, the gravity system, and the pressure system. In the first, the air and sand are not mixed in the blowing nozzle. The process is as follows : A nozzle of smaller dimensions blows the air into the discharge nozzle itself, and, by an effect similar to that of an injector, sucks the sand from the reservoir and then projects it through the discharge nozzle. It is on this same principle that the gravity system is based, in which the sand is brought mechanically above the nozzle and thence falls into the current of air.

From the fact that the compressed air produced by the compressor must always before reaching the discharge nozzle expand in the ratio of about 1 : 2 to permit the sucking up and fall of the sand, a large part of the energy of the compressed air current is lost. In the pressure system, on the contrary, the sand is mixed with the air in a pressure reservoir and projected through one single pipe, under the full pressure of the compressor, to the discharge nozzle.

The full utilisation of the work done at the compressor and the much higher efficiency which results from this rénders this the most satisfactory method.

It is only by means of this system, for which the « Alfred Gutmann A. G. für Maschinenbau », of Altona-Ottensen, took out the German patent No. 75818, that the sand blast apparatus has found such multifarious applications.

The sand jet that the compressed air drives before it meets the part being cleaned with the full velocity which has been given to it by the compressed air. The grains of sand rebound on the object and detach the scale and rust particles.

The harder and drier the material to be treated, the more promptly does the sand jet attack it. It is not essential for the sand to be harder than the material operated upon. Nevertheless, better results are obtained with good quartz sand than with ordinary building sand.

The use, rather frequent in America, of steel particles is less widely spread in Germany because there are few cases where the use of steel particles is really justified. Advantageous use can be made of steel particles for cleaning red hot steel castings, because it is necessary to break and remove a very hard coating. Here quarts sand is less convenient because the higher air pressure which is necessary has the effect of pulverising it before it attacks the hard skin.

It is therefore preferable to select a blast of sharp pointed steel particles; similarly, the steel blast may be used for cleaning the frames of railway rolling stock, when they are covered with a layer of dirt, rust and paint which acts elastically and can only be attacked by means of a higher air pressure. However, for the normal cleaning up of mild steel parts, of plates or sections, the use of the steel blast appears to be inadvisable, especially in the form of round grains, seeing that the metal does not in itself possess the properties necessary to make the cleaning a success.

Above all, the steel does not give the polishing effect which characterises quartz sand, and experience has shown that the rust is hammered and fixed on the surface by the shock of one metal on another. But, as regards the use of the steel blast, it is the question of the higher costs involved which counts.

Without doubt, the quantity of dust thrown off is less, and for that reason the dust exhausting apparatus may be smaller. But this economy only represents a small fraction of the increased consumption of energy for the compressor.

As the specific weight of the steel sand is equal to four times that of quartz sand, it is necessary to have, for an equal effort an almost double pressure at the compressor, and that not because of the cleaning effect, but simply to give to the heavy steel sand the necessary velocity.

Now, the compressed air is the costliest element in a sand blast installation, without taking into account the effect that the higher pressure results in more rapid wear of the apparatus. In America, also, the results obtained with steel sand do not appear to be sufficiently conclusive to definitely show its superiority over quartz sand.

We should mention here another inconvenience connected with the use of steel sand, namely its tendency to become agglomerated by oxidation when the compressed air contains the smallest proportion of dampness. In consequence of the obstruction of the pipes through which the sand passes, difficulties are thereby produced which are further aggravated by the difficulty of clearing the solid masses of steel sand. For this reason, if steel sand is used, special importance must be paid to the provision of draining devices and the greatest care given to the maintenance of these.

Figure 1 shows a sand blast apparatus of the standard type made by the Alfred Gutmann Company, of Altona-Ottensen. This apparatus, which works on the pressure system, comprises two compartments, D and C, of which the top one (D) serves for the sand and is closed by a screen for sieving stones, nails, bits of wood and for foreign bodies which would impede the working of the whole apparatus.

Between the receptacle D and the chamber C there is a valve L which opens automatically under the weight of the sand it supports, when the delivery of air to the lower chamber is closed by means of the cock H; the sand then falls into the chamber C.

As soon as the air enters again, the valve L automatically re-closes, and the apparatus is again ready to function. The particular features which constitute advantages with this apparatus are the sand valve L, with its sieve placed outside the flow of sand, as well as a cleaning arrangement M by means of which any clogging occurring in the lower sand feed pipe can be immediately removed. By fitting a flexible hose with a nozzle on the pipe G, the apparatus may be used for work with a free jet, i. e. a sand jet that the operator directs by hand on the part to be cleaned.

This type of single chamber apparatus has the disadvantage that after sand in the chamber C is used up, it is necessary to shut off the delivery of compressed air to introduce into it the new sand coming from the receptacle D through the valve L. In order, therefore, to avoid this interruption of work, however, short, recourse is had to multiple chamber installations, which function without interruption.

A pressure sand blast apparatus of this type, working uninterruptedly and completely automatically, is represented by figures 2 and 2 a. Here the sand governs, in a simple and absolutely certain manner, the distribution of the compressed air, the delivery and cutting off of which are subordinated to the consumption of sand in the cleaning nozzle.

Before starting up, the whole apparatus, i. e. the chambers C, D and E, are filled with sand, then the compressed air is admitted. Under the weight of the sand, the hopper H is alternately brought into the higher and lower positions indicated, and drives, through a rigid transmission integral with it, the distributor L which governs the admission of air into the chamber D.

By closing the cock M, the delivery of sand is cut off from the nozzles; at the same time the supply of sand through the valves F and G is stopped until, after the opening of the cock M, the flow of sand through C and H automatically puts the mechanism in motion again. The number of operations of the distributor L, and consequently also the number of times the sand is passed through the valves F and G vary, without any intervention from outside, with the consumption of sand, so that with this apparatus, the operator may devote his attention exclusively to the proper running and use of the machine itself.

Figures 3 and 4 represent a more recent type, improved in a few details, of an automatic sand blast apparatus, mounted on a revolving table. This table, which is employed in different forms for treating castings, forged parts and flanged parts, works in a perfectly automatic manner, even as regards the delivery of sand, and

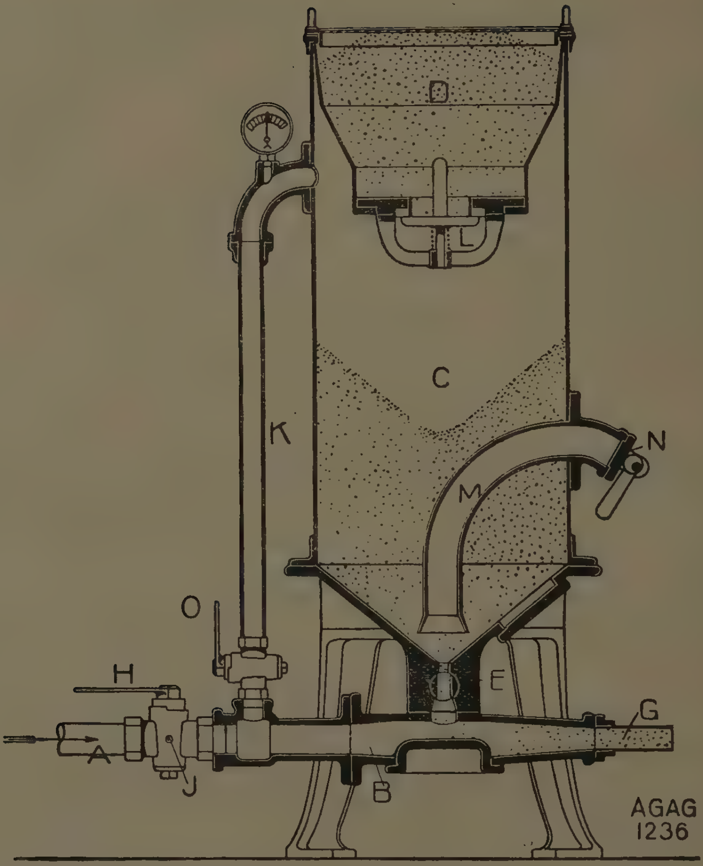
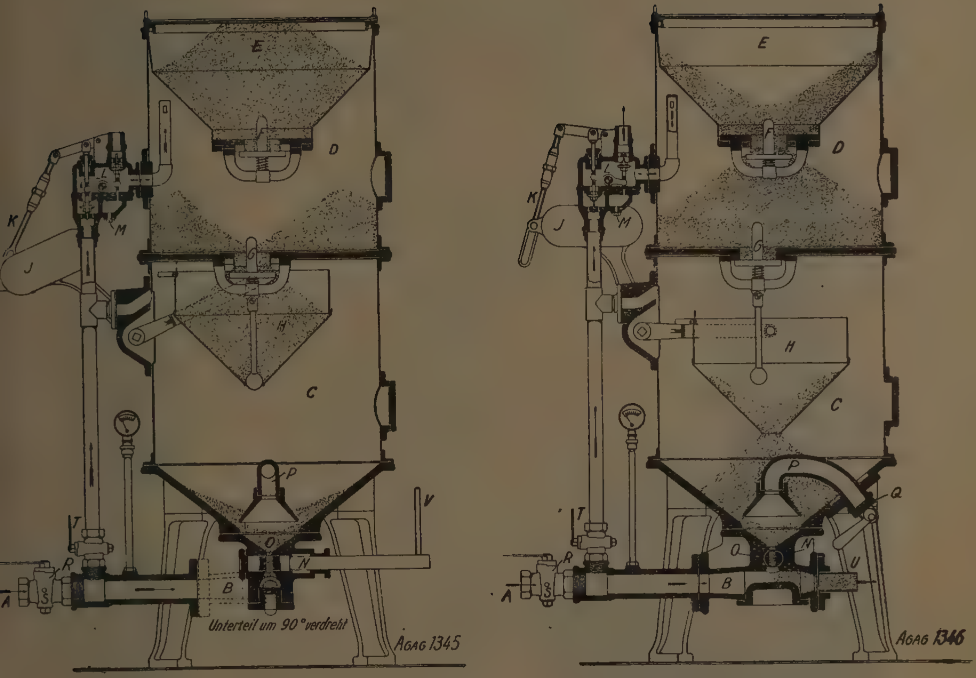


Fig. 1. — Single chamber pressure type sand blast apparatus with cleaning device German patent).

it is only necessary to open the compressed air admission at the beginning of the operation and to close it when the work is finished. The method of operation is as follows :

The sand which has been used is delivered by a bucket conveyor into the dust exhauster, where it is freed automatically of all the foreign bodies which cannot be used. It afterwards passes through the chute 1 into a tipping receptacle with two compartments 2 which is connected by a shaft to the reversing lever 3. The sand which arrives alternately fills the two compartments of the receptacle 2, and at each tipping movement of this latter the



Feeding lower chamber.

Fig. 2.

Feeding upper chamber.

Fig. 2*a*.

Figs. 2 and 2*a*. — Pressure type sand blast apparatus with automatic distribution and cleaning device (German patent).

Explanation of German terms : Unterteil um 90° verdreht = The lower portion is turned trough 90°

lever 3 operates the distributor 4 through which the compressed air is first admitted into the upper chamber of the sand blast apparatus and afterwards exhausted into the atmosphere. In consequence of this alternate admission and evacuation of the compressed air, the upper chamber is filled with sand coming from the receiver 5. The sand afterwards passes into the lower chamber 6 which communicates with the discharge nozzle 7. On leaving this nozzle, the sand falls into the nozzle 8, feeding the revolving nozzles and on to the distributing disc 9 placed in this nozzle. As the nozzle 8 is always rotating when the revolving table is working, the sand flows uniformly to the bottom of the distributing disc and passes evenly through the connecting pipe 10 to the two blast nozzles. These latter turn with the nozzle 8 round its axis of rotation and are driven by wheels which are elliptical, the effect of which is that the sand blast is practically uniform over the carrying surface of the table. It should be specially mentioned that for the two nozzles only one revolving tube is needed, the tightness of which is assured by a single stuffing box which is easily accessible from the exterior.

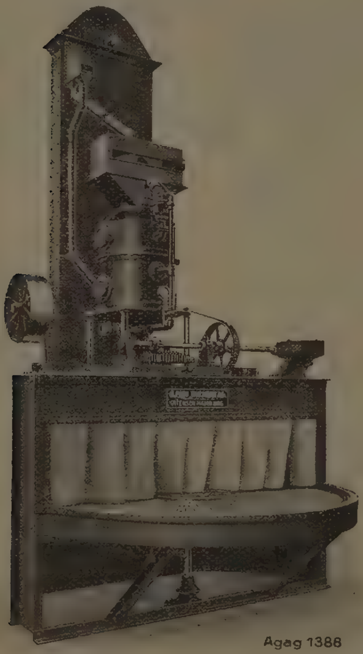


Fig. 3. - Revolving table surmounted by sand blast apparatus (German patent).

The movement of the table is operated, not from the centre of the table, but by a toothed rack fixed on its periphery. In this way, contrary to what took place with older models, which work in a jerky manner, a perfectly even movement of the table is obtained. At the moment the revolving table is stopped, the sand is automatically intercepted; in fact between the disc 9 and the lower orifice of the discharge nozzle 7 a small heap of sand is formed which prevents the flow from continuing.

The parts to be cleaned are laid on the table which is revolving slowly, and the surface of which is swept by the blast from the nozzles. As the speed of rotation is greater at the periphery than near the centre of the table, efforts must be made to produce an even effect of the surface of the latter. For this purpose, on large tables, only a certain portion of the surface is allowed to be blasted by the nozzles, whilst the central portion, which is more difficult to get at, remains free. And in order that there shall not be two great a difference between the peripheral speeds of the inside and outside circles, rather large dimensions are given to this free central part.

Experience has shown that, normally, the central part of the table must be a circle of 620 mm. (2 ft. 3/8 in.) diameter. The difference between the peripheral speeds of the inside and outside circles of the top of the table may be compensated in different manners. The oldest and simplest construction consists of a fixed split nozzle of 250 mm. to 1.500 m. (9 27/32 inches to 4 ft. 11 in.) wide, which sprinkles the surface of the table over all its width. But this construction only lends itself to the cleaning up of commercial castings, or for producing a dull finish, because it works with a low pressure. For cleaning castings covered with a hard skin and for scaling forged and flanged parts, nozzles with deliveries of smaller section are employed, to which must, however, be imparted the necessary movement in order to cover the whole working surface of the table. In this respect, the « Alfred Gutmann A. G. für Maschinenbau » after having in the first place introduced the type with nozzles having a backward and forward move-

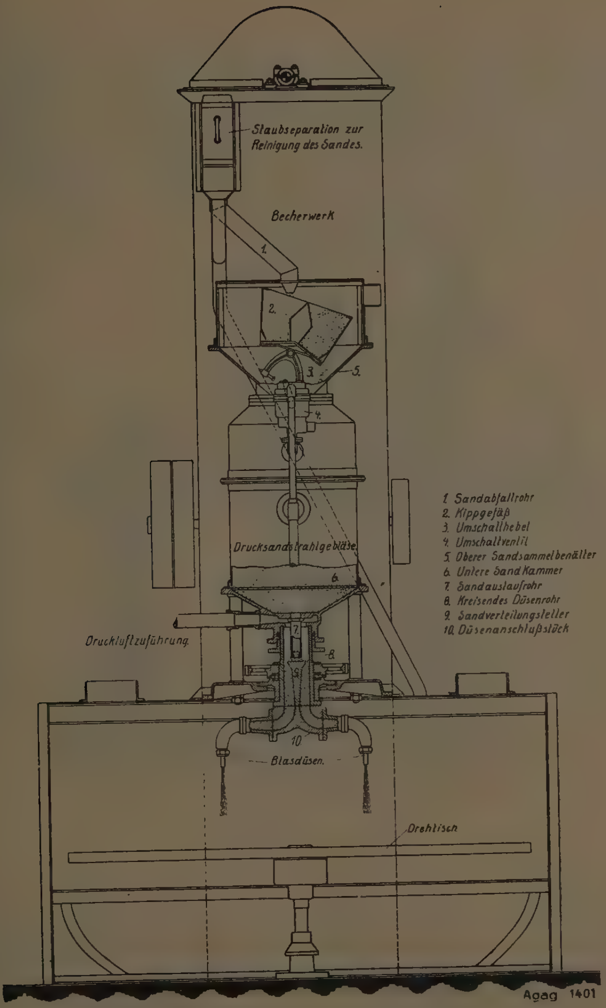


Fig. 4. — Revolving table surmounted by sand blast apparatus. (German patent) — Section.

Translation of legend: 1. Sand chute. — 2. Rocking reservoir. — 3. Tipping lever. — 4. Distributor. — 5. Upper sand reservoir. — 6. Lower sand chamber. — 7. Sand discharge pipe. — 8. Pipe with revolving nozzles. — 9. Sand distributor disc. — 10. Nozzle connections.

Explanation of Germans terms outside legend: Becherwerk = Bucket conveyor. — Blasdüsen = Blast nozzles. — Drehtisch = Revolving table. — Druckluftzuführung = Compressed air supply. — Staubseparation zur Reinigung des Sandes = Dust separator, to clean sand.

ment, afterwards adopted revolving nozzles, with which efforts were made to produce, by their irregular movement due to elliptical driving wheels, a compensation between the outside speed and the inside speed of the working surface of the revolving table.

Figure 5 represents the sanding diagram for a revolving table of 2.20 m. (7 ft. 2 5/8 in.) diameter with two rotating nozzles, of which the inside one rotates at a radius of 320 mm. (12 9/16 inches) and the outside one at a radius of 360 mm. (14 3/16 inches) round the axis of the nozzle which feeds them.

The neutral central portion of the table has a diameter of 620 mm. (2 ft. 3/8 in.). The sanding diagram is established on the basis of an annular sector of 10 000 mm². The sand blasting varies with the speed of the nozzles. At all points of the surface of the table, which are at an equal distance from the centre of the table, the speed of the nozzles is the same. Consequently the sand blasting is uniform over all the points of any concentric circumference. A change only takes place in the sand blasting when the nozzle passes from one circumference to the other. This transition, and the change of speed which results from it, must be carefully studied in the sanding diagram, for

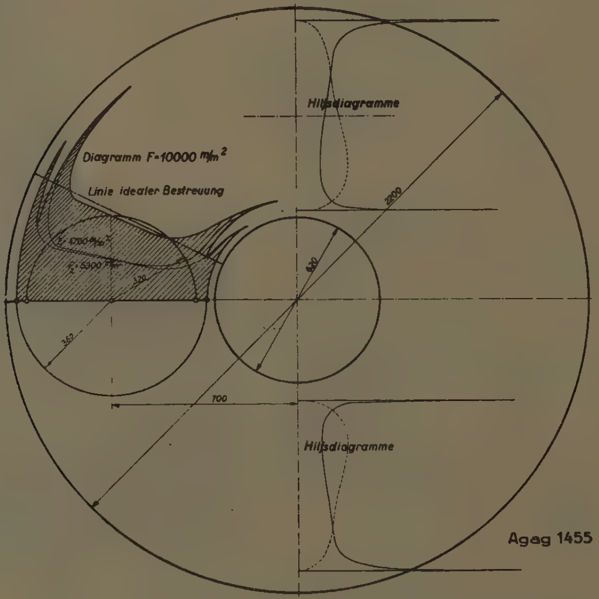


Fig. 5. — Distribution of intensity of sand blast for revolving table in figures 3 and 4.

Translation of German terms :

Hilfsdiagramme = Auxiliary diagram. — Linie idealer Bestreuung = Line of ideal distribution.

the establishment of which it is necessary to determine at any point of the table, the speed at which the nozzle moves radially in relation to the centre of the table. As a basis for the sanding diagram, a horisontal radius has been chosen, then the sanding surface of 10 000 mm² (15.5 sq. inches) has been shown by observing that the intensity of the blast decreases towards the centre of the table in proportion to the decreasing perimeter, to become nil at the centre of the table.

We thus obtain as a limit-curve for the ideal sanding a straight line which is a radius limiting, the annular sector of 10 000 mm². The ordinates measured as arcs of a circle give a measure of the intensity of the sand blasting, and the more the actual sand blasting diagram differs from the ideal the less satisfactory is the performance. As the result of the introduction of elliptical wheels in the driving mechanism, it has been possible to make the effective sand blasting on the table agree sufficiently with the ideal sand blasting to cause, as figure 5 shows, the unhatched surfaces to disappear almost altogether from the diagram.

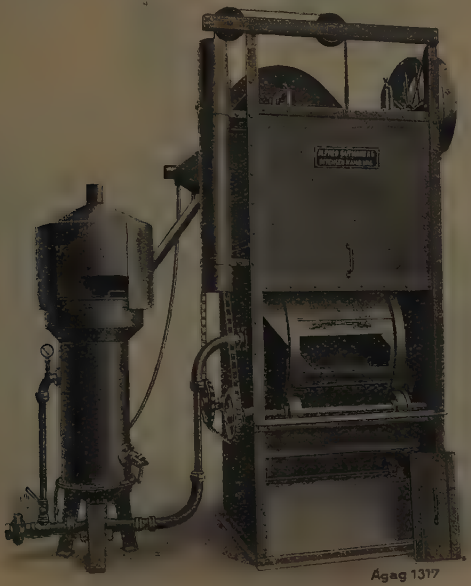


Fig. 6. — Revolving drum with sand blast. — New type with fixed nozzle.

Figure 6 shows a revolving drum sand blasting apparatus, which enables large quatities of small parts of all kinds to be cleaned which cannot be treated individually. The disadvantages of the old type of drum are well known.

In consequence of the rapid rotation and the resultant rubbing the parts are easily damaged and broken. Moreover, the angles and edges are badly rounded, whist the cavities are not reached by the cleaning operation.

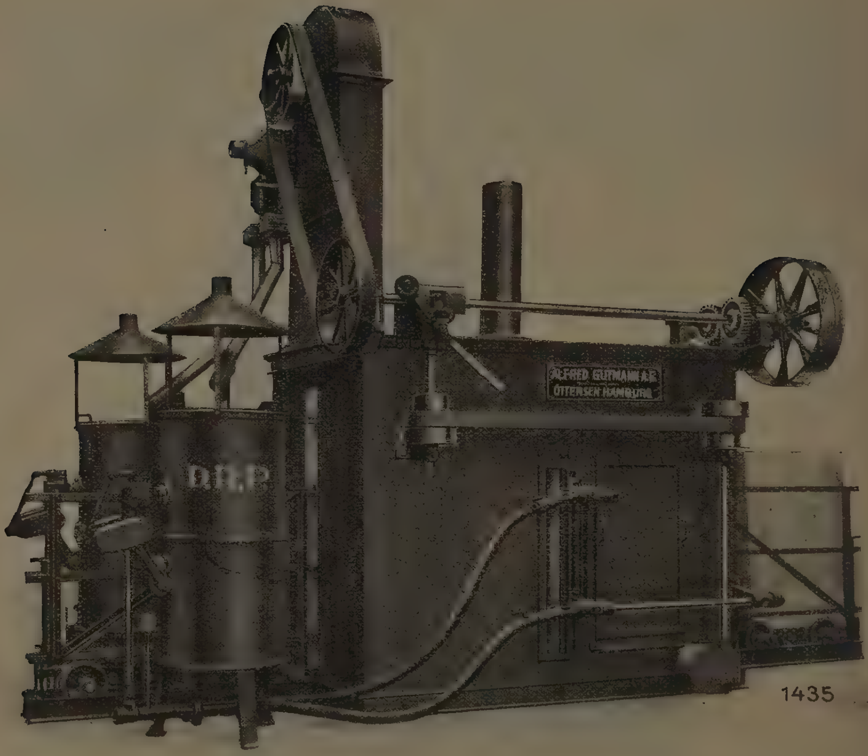


Fig. 7. — Sand blast apparatus for scaling plates.

As regards the new revolving drums with sand jet blowers, the object to be cleaned is introduced through an opening in the drum, which is then set in motion after the door of this opening has been closed. The covers, which are of special construction, give to the different parts being treated a lateral movement, which in conjunction with the radial movement of the drum, causes the object to be continually turned over in every direction, with the result that all the faces of each part are successively exposed to the sand jet.

The nozzles are fixed; they are arranged at the sides and blow into the drum through openings made in the front covers. The great advantage of this arrangement is that the driving mechanism subjected to heavy wear, which is necessary for sliding or oscillating nozzles, becomes unnecessary. Moreover, it is not necessary to connect the fixed nozzles by flexible hosepipes to the blower, as is the case when movable nozzles are used; the connection may, on the contrary, be made by means of rigid pipes made of an appropriate material.

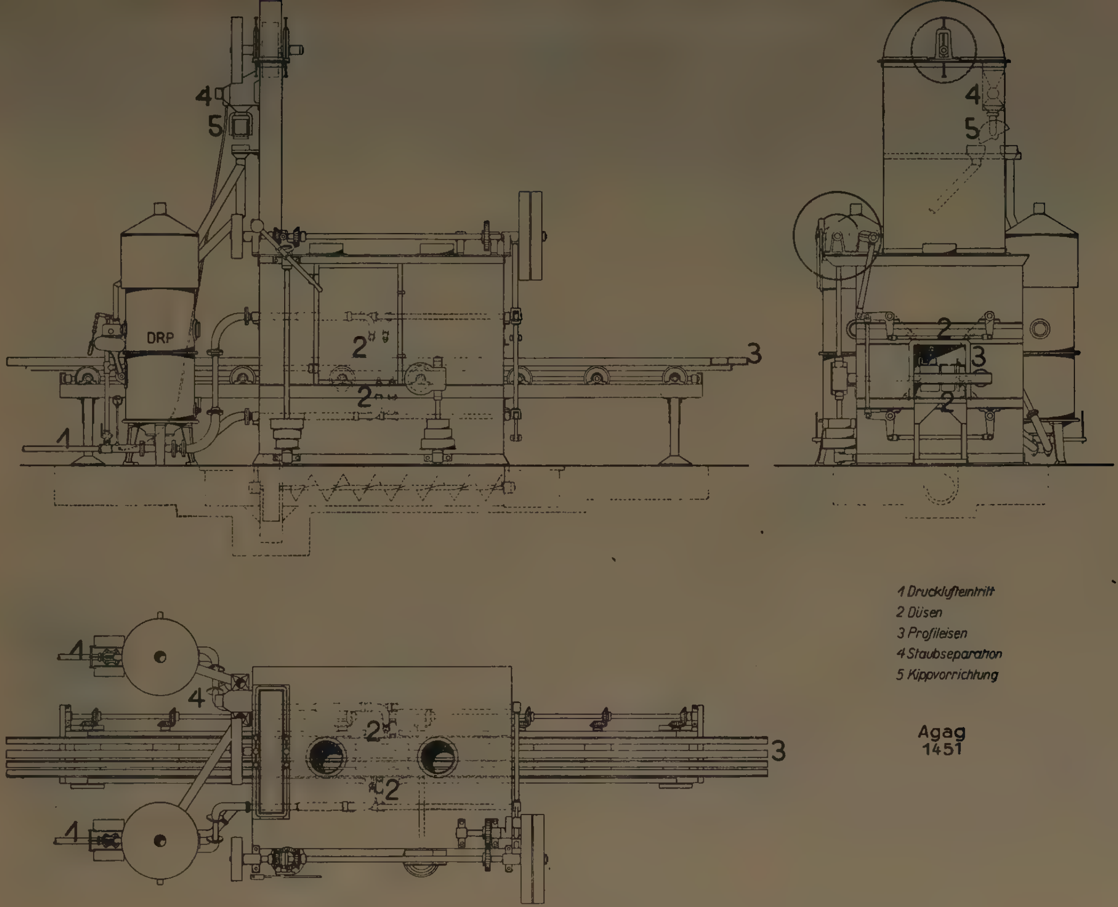


Fig. 8. — Sand blast apparatus for scaling girders, with roller conveyor (German patent).

Translation of legend: 1. Admission of compressed air. — 2. Nozzles. — 3. Rolled section. — 4. Dust separator. — 5. Tip.

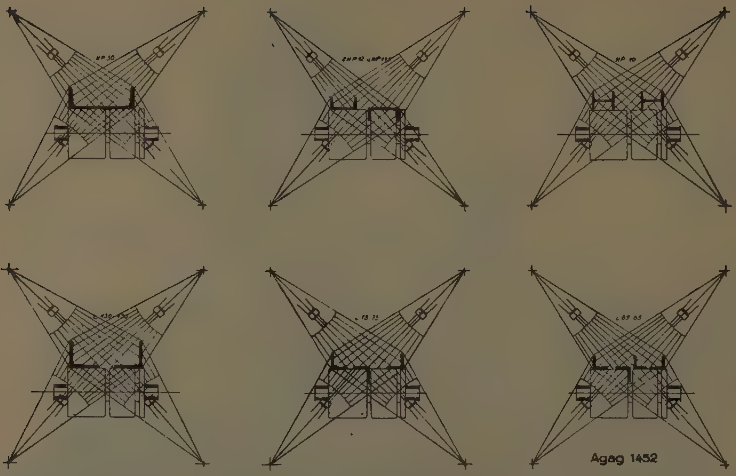


Fig. 9. — Diagram of distribution of intensity for the apparatus shown in figure 8.

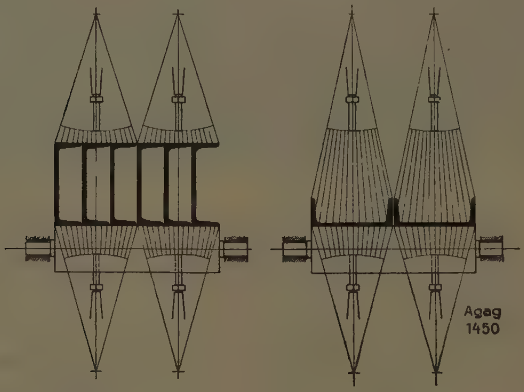


Fig. 10 — Diagram of distribution of intensity for nozzles blowing from above and below.

For feeding the nozzles, the sand blast apparatus under pressure of the type discribed above (fig. 1) is used. The sand which has been used falls through the perforated plate of the drum on to an inclined plane and afterwards drops in an elevator which takes it back to be used over again in the sand blast apparatus.

During this process the sand goes through a dust separator fixed at the end of the conveyor and which frees it of all the fine particles which are of no further use for sand blast purposes. The foreign bodies of larger dimensions are retained by the screen situated in the sand circuit. The drum is housed in a case which is closed on all sides, and which is connected with a dust removal apparatus so that the machine works without emitting dust. The drums turns freely on four rollers, and, in order to empty it, an inclined plane is employed which conveys the object which has been cleaned into a wagon or receptacle placed below.

Figure 7 shows a sand blast apparatus for scaling plates. The plates pass, standing up vertically, through the blower. The sand blast may be applied on one side or both sides, simultaneously, whilst the length of the plates has no limit. The machines are fitted, according to the width of the plates, with two or several nozzles; the width covered by the sand blast may reach 2.500 m. (8 ft. 2 7/16 in.). The length of oscillation of the nozzles may be regulated easily and rapidly. The speed of travel of the transporter can also be regulated, according to the difficulty or otherwise of removing the layer of scale. A reversing mechanism enables the direction in which the plates are moving to be instantly reversed.

With the apparatus shown in figure 7 the sand is fed by two blowers working automatically which have the advantage that the nozzles are always fed uniformly with sand, which produces a perfectly even scaling and cleaning action on the surface of the plates. For the uniform blasting of the plates, it is also important that the position of the oscillating nozzles at the dead point shall be avoided, and that the return movement shall be as rapid as possible. For this purpose, this machine is also fitted with elliptical wheels for working the nozzles.

Figure 8 shows an apparatus with a revolving drum for the cleaning of girders and rolled sections. It comprises a blower with a roller transporter of special construction which moves the girders at an even pace in front of the oscillating nozzles seen in the figure. The blower is fitted in this case with four nozzles, the length of oscillation of which can be regulated and easily adapted for the varying dimensions of the sections.

Figure 9 shows the sand blast diagram for a blasting width of 300 mm. (11 13/16 inches) for different girders and sections, the nozzles being arranged at an angle of 45° so that the parts have the surface scaled and the rust removed on all the faces by the sand jet whilst they are passing through the machine. Assuming a travel of only 1 m. (3 ft. 3 3/8 in.) per minute, this apparatus can clean in a continuous operation of 60 minutes, 60 m. (197 feet) of N. P. 30 girders over a blasting width of 300 mm. (11 13/16 inches). On the other hand, there is often to be found in sand blast machines of the same type, arrangements of girders indicated in figure 10, with twice the blasting width, viz. 600 mm. (1 ft. 11 5/8 in.) which only permits half the speed of travel, viz. 500 mm. (1 ft. 7 11/16 in.) per minute.

In this machine, the nozzles are arranged in such a manner that during the course of one passage through the machine it is only the upper and lower faces of the girder which are cleaned; the result is that, for the first passage through the machine, six girders placed on their edges are blasted on two sides at the top and bottom, four of the six girders, on coming out of the machine, are withdrawn from the transporting rollers, and two of them are laid one beside the other and introduced for a second passage through the machine, then, for the third passage, the next two, and finally, for the fourth passage, the last two. This machine therefore accomplishes half as much work as that shown in figures 8 and 9 without taking into account losses due to the removal and replacement of the sections for the second, third and fourth passages. Thus not only is the output decreased, but also the operations are interrupted in an appreciable measure. On the other hand, with the machine shown in figure 8 it has been possible to increase the speed of travel to 1.500 m. (4 ft. 11 in.) and even to 1.750 m. (5 ft. 9 in.) per minute, with the result that increases in output of 50 % and 75 % have been obtained. With a speed of travel of 1.500 m. per minute, this machine has scaled and cleaned in a perfectly satisfactory manner 90 m. (295 feet) of « U » section of the standard No. 30 profile or 180 m. (590 feet) « U » section of the standard No. 10 profile, or 230 m. (755 feet) of 80 × 80 (3 1/8 × 3 1/8 inch) angle irons.

Figure 11 shows a sand blast apparatus « Gutmann-Pontani » type, for cleaning locomotive boilers. In many cases it is possible to prevent to a certain extent the formation of scale in these boilers by a suitable treatment of the feed water. Nevertheless, at fixed intervals, it is necessary to remove the scale, especially in travelling steam boilers, like locomotive boilers, for which purifying of the feed water is not possible everywhere. However, water purifiers in the majority of cases only give imperfect results, for they cannot prevent the formation of a thin layer of scale which has to be removed when carrying out an internal inspection of the boiler, the object of which is to ascertain the extent and depth of the rust formation. Now, as this thin layer of scale is hard to chip off with the scaling hammer, this method of cleaning is always very difficult and costly. For this reason, the scaling is put off as long as possible, until the scale has become so thick that it can only be removed more or less rapidly by means of machine tools. From the point of view of thermal economy, enormous waste results. Moreover, the mechanical cleaning of boilers by means of scaling hammers or pneumatic chisels often causes notches or nicks by which the skin of the steel is more or less injured and which also offers a favourable base for scale deposits when they are formed again, and on which they adhere more strongly.

The « Gutmann-Pontani » sand blast apparatus cures the inherent inconveniences in this method of mechanical cleaning; it enables smooth and clean surfaces to be obtained, the scale which covers the walls of the boiler, being easily and thoroughly removed without deterioration of the rolled surface of the plates, including the scale which covers the rivets and joints, even when it is only a thin layer. Consequently, the boiler can be cleaned more frequently, and the cleaning is always appreciably more economical than with the hammer or by chemical methods, and at the same time the plates are spared to the greatest possible extent at the rivetted joints.

Other advantages of this system, which Mr. Pontani mentions in an article published in the review *Zentralblatt für Gewerbehygiene* are that the workman who operates the apparatus only needs to go into the boiler for a short time for the purpose of placing the de-scaling apparatus in position, and that during the actual cleaning he does not remain in the boiler; that the dust which is caused is immediately drawn off and does not escape to the outside; that the operation is noiseless; that the points that the workman could not clean or could clean very badly with the older methods are cleaned like the rest; that the work only takes up from one quarter to a sixth of the time which was necessary before, which is very advantageous in saving the time take by locomotive repairs, and finally, the cost of the cleaning operation has been about halved.

The Gutmann-Pontani apparatus used a jet of sand issuing from a nozzle which is fixed on a hollow shaft and advances along the barrel as required, the jet revolving at a given speed. The sand is supplied from an apparatus of the normal type G and is led through the hollow shaft H which is provided with a gland St to allow rotation and a nozzle D. The rotational and lateral movements are provided by the motor M which is carried on a standard gauge truck and is capable of vertical and horizontal adjustment. An exhauster fitted on a dust collector mounted on the dome of the boiler draws off the scale which the sand blast reduces to a fine powder while the sand remains at the bottom of the boiler and is again utilised for the sand blast after having been cleaned in a simple sand separator.

As regards the consumption of sand and the efficiency of the Gutmann-Pontani apparatus, Mr. Vogelsang, Chief of the Karlsruhe Workshops has published some very remarkable results of tests in the review *Das Eisenbahnwerk*. These tests were made to determine how many times the sand can be re-utilised in the sand blast apparatus and what proportion of new sand had to be added to obtain the most economical results.

Tests were carried out on some locomotive boilers of 1.500 m. (4 ft. 11 in.) diameter which had a very thick coating of scale. New nozzles were used on each test to eliminate as far as possible the effect of wear of the nozzles. The results of these tests can be summarised as follows :

With a rate of feed of the nozzle of (33 mm. (1 5/16 in.) per minute it was found that 100 kgr. (220 lb.) of new sand cleaned a boiler surface of 8.28 m^2 (89.12 sq. feet) in 53 minutes, which is equal to 12.08 kgr. of sand per square metre (2.47 lb. per sq. foot). The sand used for the second time cleaned 6.45 m^2 (69.42 sq. feet) of surface in 41.5 minutes. The sand employed for the 3rd time cleaned 6.12 m^2 (65.87 sq. feet) in 37 minutes, while the sand empoyed for the 4th time cleaned 4.70 m^2 (50.59 sq. feet) in 30 minutes. After this the sand was incapable of further economical employment.

From these results it follows that for continuous service it will be necessary to add 32.4 % of new sand for each boiler cleaned. In view of the possibility of using the sand four times the consumption of new sand is only 4 kgr. per square metre (0.808 lb. per sq. foot) of boiler surface which represents an appreciable economy. With a rate of feed of the nozzle of 33 mm. (1 5/16 inches) per minute each square metre of boiler surface required on the average 6.4 minutes (0.594 minute per sq. foot).

Up to the present about 60 of these apparatus have been supplied to various railway shops and locomotive builders in Germany and in foreign countries.

Figure 12 shows an apparatus for cleaning round bars and gas pipes which may also be used for cleaning locomotive tubes. It includes a sand blast apparatus with automatic means for returning and cleaning the sand, and a conveyor which by means of the arrangement of the rollers and their bearings causes the round bars to turn on their own axis and at the same time to acquire a forward movement at a speed which can be easily regulated. The direction of this movement can be instantly reversed. The nozzles are fixed and directed downwards and rigid piping without any rubber hose pipe connects them to the sand blast apparatus.

For cleaning the fireboxes of locomotives and for cleaning the outside of boilers it is considered preferable to use a portable jet. In this case it is necessary that the worker who operates the plant and who directs the jet of sand against the surface to be cleaned by hand should wear a helmet which protects him from the dust. For the purpose of cleaning the ends of smoke tubes and water tubes in locomotive boilers, the apparatus shown in figure 13 is used, this being fitted with a fixed nozzle directed forwards and with an air jet aspirator made integral with the apparatus which draws off the sand. The apparatus is fitted with rollers to carry the tubes and a plate with an adjustable stop. It is also provided with an opening and a glass window so that the operation of cleaning can be kept under observation.

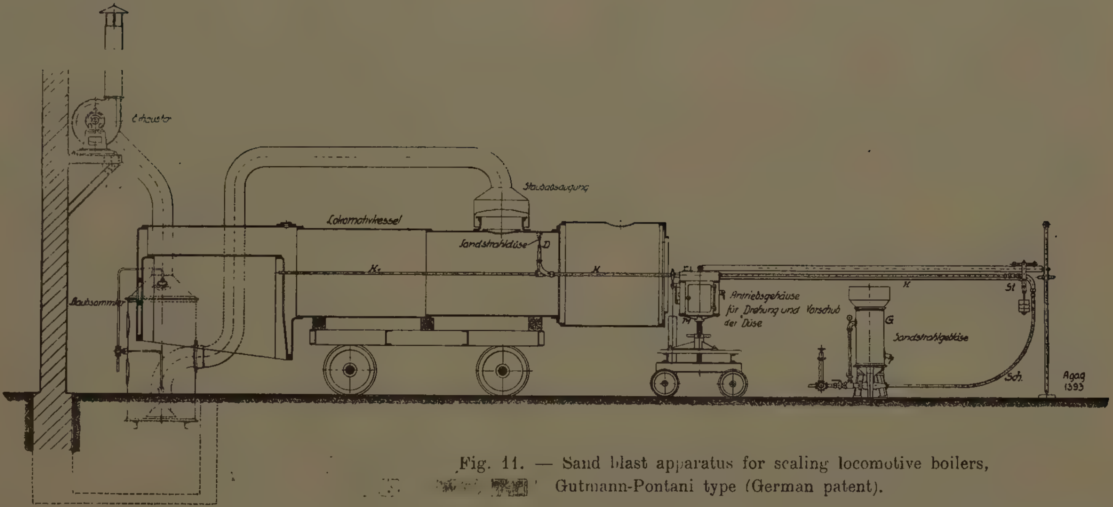


Fig. 11. — Sand blast apparatus for scaling locomotive boilers, Gutmann-Pontani type (German patent).

Explanation of German terms: Antriebsgehäuse für Drehung und Vorschub der Düse = Motor for rotating and traversing the nozzle. - **Exhaustor** = Exhauster. — Lokomotivkessel = Locomotive boiler. — Sandstrahlgebläse = Sand blast apparatus. — Sandstrahldüse = Sand blast nozzle. — Staubsammler = Dust collector. — Staubsaugung = Dust exhauster.

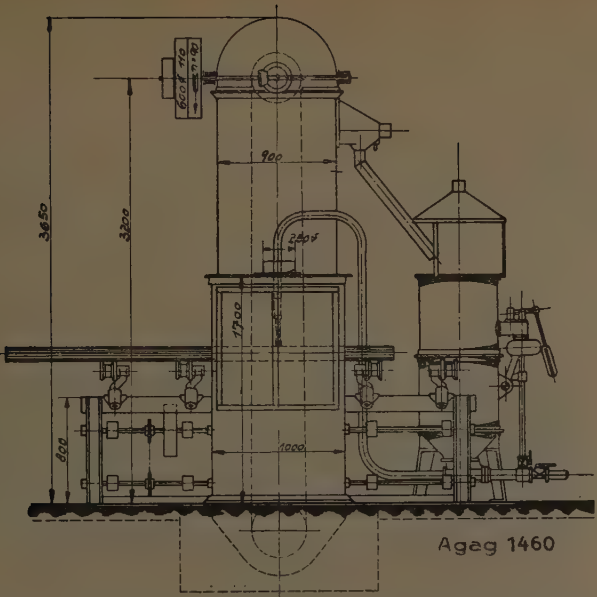


Fig. 12. — Machine for cleaning round bars, gas pipes and locomotives tubes.

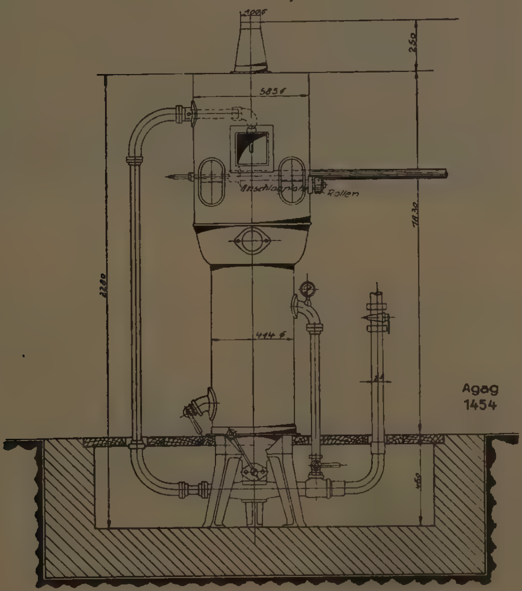


Fig. 13. — Sand blast apparatus for cleaning the ends of smoke tubes and water tubes for locomotive boilers.

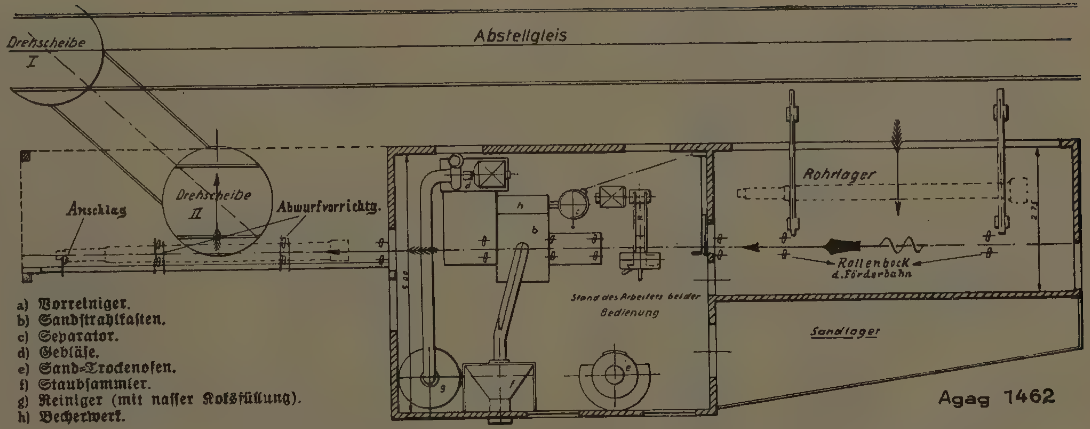


Fig. 14. — Cleaning smoke tubes by means of a steam jet apparatus in a railway works at Esslingen.

Translation of legend: a. Preliminary cleaning; *b.* Sand reservoir; *c.* Separator; *d.* Blower; *e.* Sand drying chamber; *f.* Dust collector; *g.* Filter filled with broken coke; *h.* Bucket conveyor.

Explanation of German terms outside legend: Abstellgleis = Siding. — Abwurfvorrichtung = Rollers for removing finished tube. — Anschlag = Stop. — Drehscheibe = Turntable. — Rohrlager = Support for tubes. — Rollerbock d. Förderbahn = Roller conveyor. — Sandlager = Stock of sand. — Stand des Arbeiters bei der Bedienung = Position of operator.

Figure 14 shows a complete plant for cleaning locomotive tubes by sand blast in a railway repair shop. The cleaning of tubes in tumbling drums having been found inefficient, the use of a sand blast has in this case also been found to give the best results, after a preliminary cleaning in an ordinary scaling machine in the form of a lathe with an oblique corrugated roller the purpose of which is to remove all the scale from the tubes except a light layer of uniform thickness. By means of this preliminary cleaning the rate of feed of the tubes may be increased to 1 m. (3 ft. 3 3/8 in.) per minute.

In figure 14 taken from an article by Herr Schneider published in the review *Das Eisenbahnwerk*, volume 26, year 1926, the tubes as they arrive are placed on a support; from there they roll down inclined planes on to a roller conveyor which, driven mechanically, gives the tubes a helicoidal rotatory movement by which they are carried towards the conveyor. The tubes are first dealt with in the preliminary scaling machine *a* mentioned above and thence passed to the sand blast apparatus *b*, afterwards being removed automotically by means of a trip worked by the tube itself, the tubes rollling down on to a wagon placed on turntable 2 to be taken by means of turntable 1 to the place where they are required.

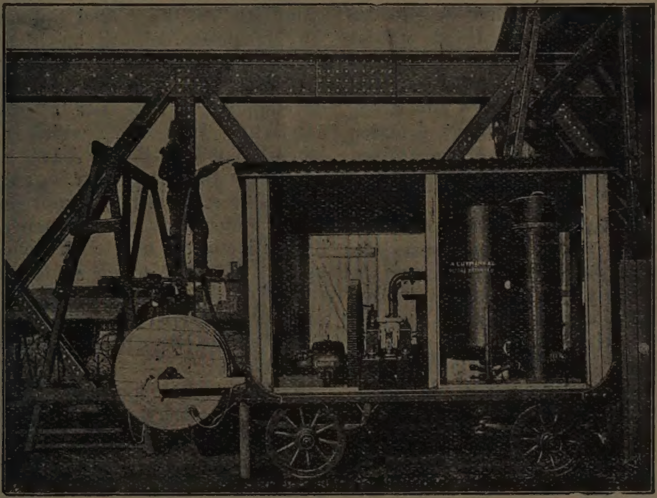


Fig. 15. — Portable sand blast apparatus for cleaning and scaling steel structures.

For cleaning steel bridges or structures of all kinds, rail joints, facings of buildings, etc., portable sand blast apparatus, figure 15, is used for the most part. The great advantage of the sand blast is that it cleans the surfaces not only of rust but of any remaining paint, while stone buildings are cleaned of accumulations of dust and soot. The plant consists of a sand blast apparatus with an air compressor and reservoir with a motor driving an air compressor and an air reservoir, the whole being mounted on a covered wagon. The air compressor may be driven by an electric motor or preferably by an internal combustion motor so that the apparatus may be used in any place.

Figure 16 finally shows a plant of the 1927 type for filling locomotive sandboxes by means of which about 500 kgr. (1 100 lb.) of sand carried by compressed air may be supplied in an hour from the dry sand bin to the sand boxes of locomotives without any dust escaping. The new sand is introduced to reservoir 1 and is taken from there by a pocket conveyor 2 to the hopper and sand dryer 3 fitted with a sieve to exclude the large pieces. The dry sand from the stove falls into the compressed air compartment 4 and is led by two pipes 5 to two hoppers 6 under which the sandboxes on the locomotives can be placed. The conveyor and the stove are operated by motor 7.

In present day sand blast apparatus, the compressed air or in some cases the high pressure steam which is used to blow the sand is usually led in at right angles to the pipe conveying the sand; it then enters a chamber which surrounds this pipe and it is in this chamber that its change of direction takes place, the air and the sand then flowing forward together. From the fact that they then mix, the sand finally receives its greatest acceleration in the nozzle. The change of the direction of the compressed air mentioned above produced in the chamber surrounding the sand nozzle a back pressure and violent eddies so that the velocity of the compressed air suffered an appreciable reduction. Further the acceleration of the sand caused by the jet of air has a destructive effect on the nozzle. This defect is found to a greater or less extent in all the ordinary sand blast jets whether the system is by induction, by gravity, or pressure.

With simple nozzles with an annular orifice difficulties are always met with from the fact that the nozzle is smallest at the orifice, i. e. where the sand mixes with the compressed air, so that the maximum velocity of discharge cannot be obtained especially for pressures exceeding 2 at. (28.46 lb. per sq. inch) because the expansion of the compressed air takes place too rapidly without being able to give the sand the necessary velocity for effective action.

Considerable attention has been given to this point by constructors of sand blast apparatus and in a patent application which has been accepted by the German Patent Office, the Alfred Gutmann A. G. für Maschinenbau, Altona-Ottensen, put forward a novel solution which will be of great importance towards the further development of the use of sand blast apparatus. This patent, which is on similar principles to the de Laval nozzle, is based on the fact that in an annular nozzle the expansion of compressed air or steam under pressure commences before the orifice of the nozzle is reached, which has the effect of commencing the acceleration of the sand while the maximum velocity of discharge is attained immediately after air or steam has escaped to the atmosphere.

In the Gutmann apparatus, figure 17, the air inlet connects to the sand pipe in such a way that no eddies or loss of energy are produced and it is at this point where the air nozzle takes the direction parallel to the flow of sand that the air nozzle has its smallest cross section, this being increased progressively towards the common orifice of the two nozzles until it reaches the section at the orifice.

This type of sand blast nozzle allows the compressed air to flow without loss of energy, and consequently without shock, from the supply pipe to the nozzle and to issue from the latter with the maximum velocity which can be obtained from the expansion. This new type of annular nozzle also prevents the excessive wear to which nozzles in which the sand and air have to flow out of one and the same orifice are subjected. Further it allows the use of air at a pressure as

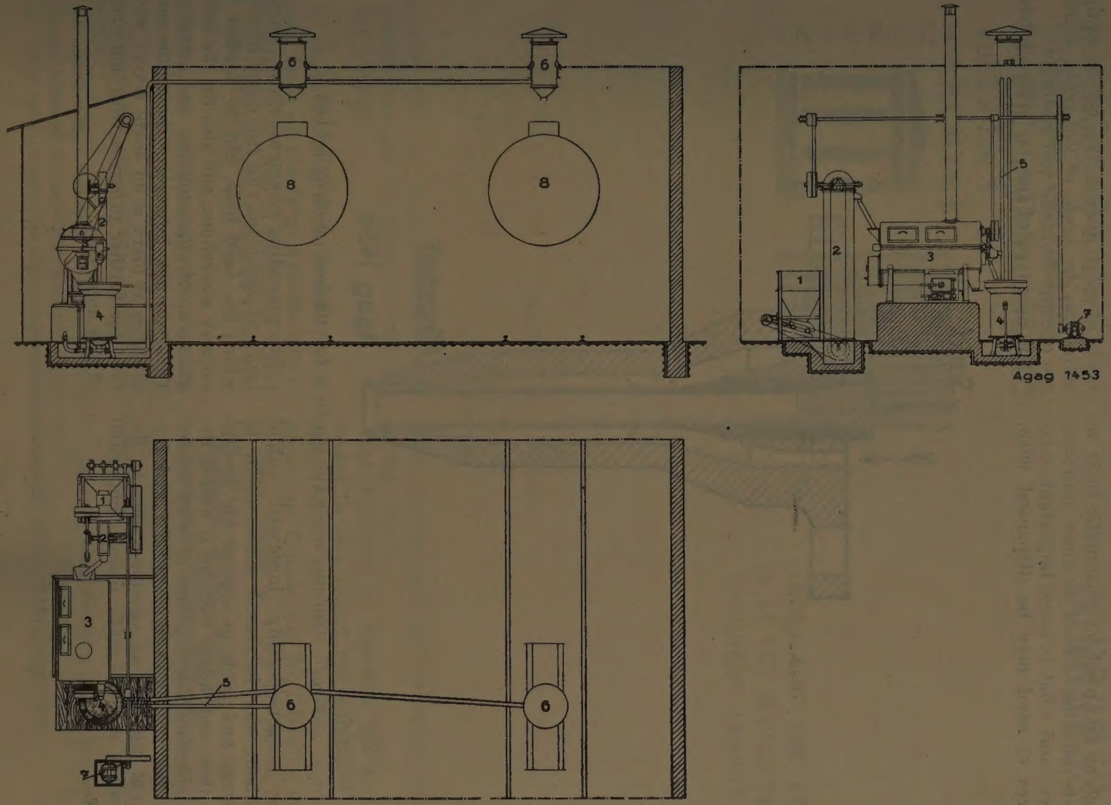


Fig. 16. — Equipment for filling locomotive sandboxes, designed for the German State Railways (Reichsbahn), 1927 type.

high as that used for pneumatic tools so that reducing valves become unnecessary, and what is more important, mixtures of sand may be dispensed with. With annular nozzles the whole equipment may be made of the types which are cheaper to make and maintain.

The new type of annular orifice produces a considerably increased output without any increased consumption of energy and leads to appreciable savings in time and wages because it avoids the troublesome interruptions of work caused by the replacement of nozzles and frequent stoppage of sandpipes due to the contact of sand with damp compressed air.

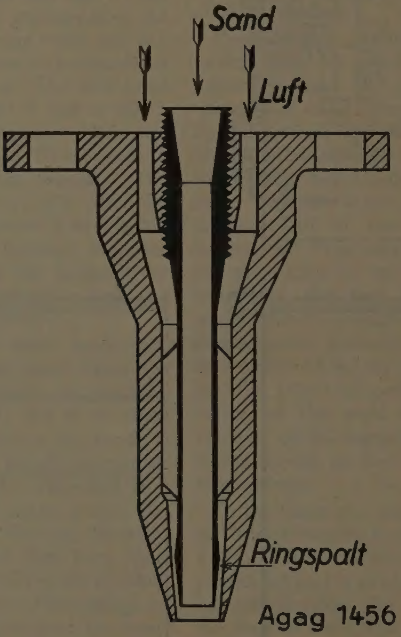


Fig. 17. — Gutmann nozzle with annular orifice (German patent applied for).

The preceding comments show various types of apparatus and the many uses to which the sand blast can be applied in railway workshops, and also for the manufacture of locomotives and wagons. These do not, however, exhaust the possibilities as there is no doubt a very wide field for further progress with apparatus of this nature.